

Arab American University
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**Integrating Building Information Modeling and Lean Principles in
Palestinian Architectural Design: Strategies for Enhancing Efficiency
and Effectiveness**

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**This Thesis Was Submitted in Partial Fulfillment of the Requirements
for the Master Degree in Engineering Management**

Palestine, Feb/ 2026

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Declaration

I declare that, except where explicit reference is made to the contribution of others, this thesis is substantially my own work and has not been submitted for any other degree at the Arab American University or any other institution.

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Acknowledgement

I would like to express my gratitude to my supervisor Dr. Ashraf Almimi, for his support, guidance, and constructive feedback throughout all of this research's stages. His insights and patience were the key in shaping the quality of this research.

Additionally, I extend my appreciation to the members of the examination committee for their time, and suggestions that contributed to this work.

I'm very thankful to my family for their encouragement and support through my journey, which provided me the motivation needed to complete this research.

Finally, I acknowledge my own commitment and perseverance throughout this research, which enabled the completion of this thesis despite academic and practical challenges.

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Abstract

The architectural design process is often affected by fragmented workflows and different types of waste that reduce projects' efficiency. The integration of Building Information Modeling (BIM) and Lean principles has been proposed as an effective approach in order to identify these challenges by improving Design Coordination, Information Flow Quality, and Collaborative Workflow in the design process. However, research investigating the application of BIM-Lean in contexts such as Palestine remains limited. This study examines the impact of BIM-Lean integration on efficiency enhancement in the architectural design process in Palestine.

The findings obtained through the adopted mixed-method research approach indicate that BIM-Lean integration has a positive impact on Efficiency Enhancement and reduces waste related to the architectural design process. Design Coordination was the most substantial factor amongst suggested variables, while Information Flow Quality and Collaborative Workflow supported Efficiency Enhancement and Collaborative

Effectiveness. Despite BIM-Lean integration benefits it still has obstacles that limit its effective implementation such as organizational and skill related barriers.

The study concludes that successful and effective implementation of BIM-Lean integration requires both technological adoption and organizational commitment.

Keywords: BIM-Lean integration, Building Information Modeling (BIM), Lean Principles, Architectural Design Process, Efficiency Enhancement.

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List of Definitions of Abbreviations

| Abbreviations | Title |
|------------------|--|
| BIM | Building Information Modeling |
| BL | BIM-Lean Integration |
| CE | Collaborative Effectiveness |
| CW | Collaborative Workflow |
| DC | Design Coordination |
| EE | Efficiency Enhancement |
| IFQ | Information Flow Quality |
| Lean | Lean Construction/ Lean Thinking |
| IV | Independent Variable |
| DV | Dependent Variable |
| M | Mediator |
| PLS-SEM | Partial Least Squares Structural Equation Modeling |
| SEM | Structural Equation Modeling |
| AVE | Average Variance Extracted |
| HTMT | Heterotrait-Monotrait Ratio |
| CR | Composite Reliability |
| α (Alpha) | Cronbach's Alpha |
| β (Beta) | Path Coefficient |
| t-value | Significance Strength |
| p-value | Statistical Significance Probability |
| R^2 | Coefficient of Determination |

| | |
|-------|---------------------------------------|
| f^2 | Effect Size |
| Q^2 | Predictive Relevance |
| TPS | Toyota Production System |
| JIT | Just In Time |
| IPD | Integrated Project Delivery |
| CAD | Computer Aided Design |
| AEC | Architecture Engineering Construction |
| MEP | Mechanical Electrical Plumbing |
| IFC | Industry Foundation Classes |
| DBB | Design Bid Build |

Chapter One: Introduction

1.1 Background and context

In today's rapidly changing environment, the success of an organization heavily depends on its implementation and adoption of advanced technologies. Similarly, the architecture, engineering, and construction (AEC) industry is going through a major transformation with the adoption of such technologies. These include the adoption of lean practices and Building Information Modeling (BIM), whose goals are to improve efficiency, enhance collaboration, optimize project outcomes, cost effectiveness, and reduce waste in construction and architectural design (Sacks et al., 2010).

Lean construction is the adoption of Lean thinking principles which have originated from the Toyota Production System (TPS) (Dekier, 2012), the moment this methodology has emerged and proved its effectiveness, it has influenced and was adopted by various industries worldwide, including architecture (Dekier, 2012). As explained by Badurdeen and Gregory (2012), lean is doing more with less, by utilizing less resources, and reducing waste, while promoting continuous improvement, and giving customers maximum value products, customized to their needs.

While lean follows a cyclic or a trial and error method, traditional architectural design workflows tend to be more linear, even though the process of architectural design itself has iterations in between (Hettithanthri et al., 2022). This often leads to miscommunications, delayed outcomes, and last-minute modifications. Since lean principles and goals align with the architectural design process and objectives, it drives the urgent need of adopting lean into the AEC industry. This adoption leads to significant changes

specifically in architectural design, where it would reduce rework, and result in more effective decision making (Ries, 2011).

At the same time, architectural design and construction have been revolutionized with the utilization of Building Information Modeling (BIM), by introducing a data driven platform that enables in real-time collaboration between architects, engineers, and other involved parties. As Shewale et al. (2023) note, the adoption of BIM has reduced the time usually spent on coordination, allowing engineers to focus on solving problems rather than being stuck on random errors and reworks. With BIM's intelligent model, it has significantly improved design accuracy, coordination, and project efficiency (Sacks et al., 2010).

Although the application of lean principles in the AEC industry has not been that significant and has undergone a slow transition (Moradi & Sormunen, 2023), BIM has been well-accepted and widely adopted, particularly in first-world countries. Similar to lean, BIM aims to achieve the same effective results by reducing reworks, minimizing errors, and optimizing workflows. The implementation of lean principles could further elevate industry outcomes, as both approaches share the common goal of enhancing efficiency and productivity. This highlights the necessity of integrating BIM and lean, as their combination offers significant benefits (Landim et al., 2022).

The majority of recent studies show the importance of digital transformation in the AEC industry, as it became essential in order to keep a competitive edge, “digital transformation has become a global development trend and a core element of sustainable development in construction.” (Liu, 2024). As recorded by Kudryavtseva et al. (2020):

In relation to investment and construction, digital transformation has an impact on many aspects of society's like, for example. It reduces construction costs, increases

the efficiency of construction organizations, reduces the negative impact of construction on the environment, and increases the pace of economic development both at the level of individual regions and countries and at the global level.

The integration of Building Information Modelling (BIM) and Lean construction has been recognized as a strategic approach in order to resolve issues in the AEC industry such as inefficiency, lack of coordination, and disconnection (Evans & Farrell, 2020; Bayhan et al., 2022). In their research Jindal et al. (2023) have highlighted the framework made by Sacks et al. (2010) intersecting BIM and Lean construction, which led them to concluding the benefits of this combination as it reduced barriers and obstacles by enhancing quality and speeding up the process.

Moreover, in their research they mentioned another matrix made by Bhat et al. (2018) which helps increasing the project value, “Bhat et al. (2018) have created a matrix to increase the construction sector’s productivity by addressing the BIM features and Lean construction concepts. Though the course of a project’s life cycle, integrating BIM with Lean implementation may increase project value.” (Jindal et al., 2023).

For developing contexts like Palestine, it is important to adopt such strategies. As confirmed by Bayhan et al. (2022) the combination of BIM and Lean enable organization to respond quickly to Market uncertainties while fostering innovation. Uncertainty is what the Palestinian market facing and suffering from the most. The adoption of this integration will help to reduce waste and enhance collaboration and coordination (Shewale et al., 2023).

1.2 Building Information Modeling (BIM) and Lean in the AEC industry in Palestine

Even though there is a critical need for the integration of BIM and lean, it still faces many challenges that require strategic solutions especially in Palestine. Engineering and

architectural firms in Palestine struggle with many obstacles trying to implement BIM-Lean into their culture, including regulatory and standardization barriers, resistance to change and traditional mindset in design and construction, technological and infrastructure limitations, lack of BIM training, and the complexity of implementing BIM-Lean (Fasasi, 2024).

According to Albatsh (2015) most of the projects that were and are being constructed in Palestine, still follow traditional delivery techniques like Design Bid Build, in this technique the construction happens in separation to the design process, as independent firms handle each process. This leads to disconnected processes, insufficient and ineffective coordination, and the detection and solving of conflicts takes longer periods of time (Sbeih, 2024).

When it comes to regulations Palestine lacks a coherent construction policy or a legal framework that could enable BIM or Lean approaches. As stated by Enshassi and AbuHamra (2017) the current codes that are being practiced in construction are out of date, not always applied across different municipalities, and these codes are not strictly enforced either. According to Sbeih (2024) the lack of national BIM standards and guidelines makes it difficult for firms to successfully and effectively adopt new technologies that aligns their practices with the international standards.

Enshassi and AbuHamra (2017) in their research explain how in terms of finance the majority of the Palestinian engineering and architectural firms work with limited resources, where medium and small firms cannot afford the initial investment of BIM adoption. On the other hand, they also explain how some firms are aware of the benefits of BIM and are willing to pay to gain those benefits “the initial costs that must be spent in the beginning will

not affect the organization for a long time as there are great benefits to be gained from BIM adoption in the long run” (p. 3).

Culturally, professionals in AEC industry in Palestine have found themselves comfortable and experienced with the traditional tools used for design such as AutoCAD and other outdated design tools, while as founded by Enshassi and AbuHamra (2017) BIM remains to be unfamiliar to a significant portion of the engineering workforce. In his research Sbeih (2024) draws the attention to the skill gap between architecture graduates who may have had some exposure to BIM, and engineers in other fields who lack training in Lean or BIM tools, this causes coordination issues and limits the benefits of an integrated project delivery. Moreover, the rigidity in some firms in Palestine hinders collaboration and flexible teamwork that are supported by both BIM and Lean.

Despite the challenges that come with the implementation of BIM-Lean integration, its pros overweigh its cons, which makes it a worthwhile investment in the AEC industry in Palestine (Sbeih, 2024). BIM-Lean integration has potential to transform the outcomes of projects from planning, management, and control of projects, this transformation leads to better efficiency, sustainability, and maintaining a competitive edge in the AEC industry in Palestine (Sacks et al., 2010; Bayhan et al., 2022; Sbeih, 2024).

As stated by Sacks et al. (2010):

The high number of interactions between BIM and lean suggests that perhaps the parallel adoption should be in small steps. It may be a good strategy to carefully define benefits that are desired, accordingly to design and execute manageable BIM/lean experiments, and to proceed in incremental stages towards harnessing even more positive interactions between these two initiatives. (p. 18-19)

In summary, the AEC industry in Palestine faces many challenges technical, organizational, and legal, these challenges limit digital and process innovation. These issues provide clear evidence of the need to combine digital approaches (BIM) with managerial methods (Lean) to improve efficiency, coordination, teamwork, and overall project performance. Therefore, this study explores how BIM and Lean integration can overcome these challenges and strengthen the architectural design process in Palestine.

1.3 Research Problem

In various industries lean principles have been adopted due to their significant outcomes (Dekier, 2012), yet in the Architecture, Engineering, and Construction (AEC) industry, the adoption of Lean principles has been gradual and slow due to various barriers (Moradi & Sormunen, 2023). BIM, on the other hand in the AEC industry have been embraced fast, especially in the first-world countries, as a digital tool that enhanced efficiency, reduced rework, and minimized errors.

Similar to BIM, Lean practices strives to achieve the same outcomes, eliminating waste, increasing efficiency, promoting continuous improvement, and optimizing workflows. Despite the evident synergy between BIM and Lean (Hattab & Hamzeh, 2015), these two methodologies are often used independently, this limits the industry's ability to fully benefit from their combined advantages.

In Palestine, the implementation of the integration of BIM-Lean is more challenging because of several limitations and barriers. While in other countries, BIM has been embraced and implemented, in Palestine the adoption of BIM is very low (Enshassi & AbuHamra, 2017; Saleh & Bakri, 2021), as many firms operate under traditional construction and design practices, using outdated software like CAD. Even though the BIM

adoption is low, it's still used by some firms, while the adoption of Lean principles is largely absent, especially from architectural and construction practices. The implementation of BIM and Lean separately still face many challenges, same challenges might apply to the adoption of their integration.

The AEC industry may have a great opportunity to transform to the better, considering that BIM and Lean share the same goal of eliminating waste and increasing efficiency, with a successful implementation of their integration these results might not be impossible. Despite extensive studies on Lean and BIM individually, limited research has explored their combined application in developing contexts such as Palestine. Hence, the research problem main focus is to determine how Lean principles can be successfully and effectively integrated with Building Information Modeling (BIM) to improve project outcomes, particularly in Palestine, where their adoption faces many challenges.

1.4 Research Questions

The research is guided by multiple research questions, these questions offer a thorough understanding of the study and proposed hypotheses, they are as follows:

- **RQ1:** Does BIM-Lean integration impact Design Coordination (DC) between specialists in architectural projects?
- **RQ2:** Does BIM-Lean integration impact information flow quality (IFQ) among project stakeholders?
- **RQ3:** Does BIM-Lean integration impact Collaborative Workflow (CW) in the architectural design process in Palestine?
- **RQ4:** Does Design Coordination (DC) contribute to Efficiency Enhancement (EE) in the architectural design process?

- **RQ5:** Does Information Flow Quality (IFQ) contribute to Efficiency Enhancement (EE) in the architectural design process?
- **RQ6:** Does Collaborative Workflow (CW) enhance the effectiveness of interdisciplinary collaboration (Collaboration Effectiveness (CE)) in the architectural design process?
- **RQ7:** To what extent do collaborative workflow, information flow quality, and design coordination mediate the relationship between BIM-Lean integration and project outcomes?

1.5 Research objectives

The research's objectives is to investigate how BIM-Lean integration impacts the project outcomes in the architectural design process, the following objectives reflect the research's questions and hypotheses:

- **RO1:** Investigating the impact of BIM-Lean integration on Design Coordination (DC).
- **RO2:** Evaluating the impact of BIM-Lean integration on the Information Flow Quality (IFQ) among the project stakeholders.
- **RO3:** Assessing the impact of BIM-Lean integration on Collaborative Workflow (CW).
- **RO4:** Evaluating the role of Design Coordination (DC) and Information Flow Quality (IFQ) in Efficiency Enhancement (EE) in architectural design.
- **RO5:** Determining the impact of Collaborative Workflow (CW) on Collaboration Effectiveness (CE) in the architectural design process.

- **RO6:** Identifying if collaborative workflow, information flow quality, and design coordination mediate the relationship between BIM-Lean integration and project outcomes.

1.6 Research Hypotheses

Aligning with the research problem, questions, and objectives, a set of research hypotheses has been formulated. These hypotheses were constructed according to the proposed conceptual framework, the framework represents the expected relationships between the integration of BIM-Lean and the project outcomes in the architectural design process in Palestine. The hypotheses are presented below and tested in chapter four in order to ensure that the study is grounded in theory. This provides a clear connection between the theoretical foundations and the research investigation.

- **H1:** BIM-Lean integration has a positive impact on DC in the Architectural Design process in Palestine.
- **H2:** BIM-Lean integration has a positive impact on IFQ in the Architectural Design process in Palestine.
- **H3:** BIM-Lean integration has a positive impact on CW in the Architectural Design process in Palestine.
- **H4:** DC has a positive impact on Efficiency Enhancement in the Architectural Design process in Palestine.
- **H5:** IFQ has a positive impact on EE in the Architectural Design process in Palestine.
- **H6:** CW has a positive impact on Collaboration Effectiveness in the Architectural Design process in Palestine.

- **H7:** The relationship between BIM-Lean integration and the project outcomes (DVs) is mediated by collaborative workflow, information flow quality, and design coordination.

1.7 Research significance

In the course of architectural design process, efficiency is enhanced and wastage is reduced with the integration of Lean principles and Building Information Modeling (BIM). Although the use of BIM is increasing worldwide in architecture and the AEC industry, its expansion in Palestine remains limited, and lean principles are hardly implemented in practice. This study explores how BIM can help lean practices in optimizing design workflows, and eliminating inefficiencies in the AEC industry focusing on the architectural design process.

The architectural design process in Palestine is usually afflicted with delays, a lack of coordination, miscommunication, overproduction, rework, and so on, all these cause increased costs, and reduced efficiency. With the BIM-Lean integration, most of the problems architects and engineers face will be solved, especially communication issues as BIM-Lean enhances collaboration, it also reduces errors, and improves decision making through its real-time information sharing. However, many challenges hinder the implementation and adoption of this integration.

This research contributes to both academia and the AEC industry in Palestine by identifying key challenges and proposing practical strategies for the integration of BIM and lean methodologies. The study's findings will help architects, engineers, and policy makers enhance efficiency and sustainability in architectural design. Moreover, it will help promoting a modernizing and improving architectural design processes by addressing the

challenges faces when implementing BIM-Lean, leading to better project outcomes, and making Palestine's architectural industry more sophisticated.

1.8 Scope, Limitations, and Delimitations

1.8.1 Scope

This research investigates the integration of Building information Modeling (BIM) and Lean in the architectural design process in Palestine. The scope of the study is limited to the architectural and engineering firms that are registered in the Palestine Engineers Association, focusing on the six major cities in the West Bank, Ramallah, Hebron, Nablus, Bethlehem, Jenin, and Tulkarm. The mentioned cities have the majority of the active and high-level firms in Palestine, this ensures providing meaningful basis in order to analyse BIM-Lean adoption within the AEC industry in Palestine.

The study's primary focus is the architectural design process, it does not include the entire project's lifecycle. Investigating the relationship between the suggested variables, how BIM-Lean integration impacts Design Coordination (DC), Information Flow Quality (IFQ), and Collaborative Workflow (CW). And how these variables mediate the relationship between the BIM-Lean integration the Efficiency Enhancement (EE), and Collaborative Effectiveness (CE). Employing a mixed method approach from interviews and surveys to collect primary data, and secondary data is collected from previous research, case studies, reports, and other relevant documents.

1.8.2 Limitations

There are several limitations that this study is subjected to, regardless of the meaningful insights it provides. First, it is restricted to the West Bank, excluding Gaza and other big cities such as Jerusalem due to political and logistical constrains. Second, with the

main focus being on the architectural design process this study might leave a gap when it comes to the construction and operational phases, the integration of BIM-Lean might have significant impact on these phases.

Third, many of the architectural/engineering firms in Palestine are either small or medium in size, these firms often lack resources, training, or advanced technology for BIM adoption. Because of that, the generalizability of findings is reduced to larger firms or ones that are resourceful, even though the large firms in Palestine are not as big as those that are in first world countries. Fourth, since the data collection is based on self-reported surveys and interviews, it may represent a respondent bias or limited familiarity with BIM and Lean practices. Finally, while the study seeks broad participation, not all target firms responded, which can limit the diversity of perspectives.

1.8.3 Delimitations

In addition to the mentioned limitation, some delimitations were deliberately established in order to maintain manageability. To begin with the study focuses on the architectural design process and does not extend to operation, construction, or infrastructure projects. Furthermore, the included firms in the study were the ones that are registered in the Palestinian Engineering Association. Finally, the study is limited to professionals such as architects, engineers, and project managers. Individuals like students or trainees have been excluded to ensure that the findings of the investigation reflect the industry and its perspectives.

These delimitations were set on purpose with the aim of narrowing the scope and making sure that the findings or results from the study are practical and applicable to the architectural design process in Palestine.

1.9 Research scope and Methodological Clarification

This study adopts an explanatory, theory driven research approach. Investigating the influence of BIM-Lean integration on efficiency related outcomes in the architectural design process in Palestine. Although variations in BIM and Lean adoption levels do exist across organizations, the study does not aim to assess the adoption levels as stand-alone objects, as it is not the primary research objective. Instead, BIM and Lean practices are measured as foundational constructs in order to enable the examination of their integration in PLS-SEM framework.

Accordingly, in the study questionnaire BIM and Lean are measured as separate as each have their own section, this is to ensure construct validity and accurately assess the direct mediating effects of BIM-Lean integration on Design Coordination, Information Flow Quality, Collaborative Workflow, Efficiency Enhancement, and Collaborative Effectiveness. Strategies for enhancing efficiency and effectiveness are derived analytically from the empirical findings of the model rather than predefined as prescriptive recommendations.

1.10 Research structure

This thesis is organized into five chapters. Chapter One introduces the research background and context, research problem, questions, and objectives. Moreover, it explains the significance of the study, highlights its scope, limitations, and delimitations. Chapter Two reviews the literature on Lean Construction, Building Information Modeling (BIM), and their integration within the AEC industry and the Palestinian context, and presents the conceptual framework. Chapter Three explains the research methodology including research strategy, design, instruments, data collection, and analysis methods. Chapter Four provides the qualitative and quantitative findings and data analysis. Chapter Five “Discussion and

Conclusions” discusses the findings and concludes the thesis by summarizing the key findings and offering recommendations for both practice and future studies.

Chapter Two: Literature review

2.1 Overview

This chapter reviews the main studies related to the goals of this research, exploring BIM, Lean, and their integration, outlining their principles, adoption, application, and impact on project outcomes. It begins by exploring Lean and its adaptation in the architectural process, followed by a detailed review of BIM and its use as a digital tool for project delivery. Investigating BIM-Lean integration, their synergy, and how they influence information flow, coordination, collaboration, and teamwork.

Towards the end of the Literature review, it focuses on the Palestinian context, particularly the AEC industry, highlighting how Lean and BIM are underutilized locally. The chapter then concludes by demonstrating the relationships between suggested variables in the conceptual framework.

2.2 Lean Construction

Lean thinking originated from Toyota Production System (TPS), which has been applied worldwide in various industries like manufacturing and construction. It was mainly utilized to optimize processes, reduce waste, and maximize value. “The Toyota Production System did not arouse interest in Japanese and American companies by 1973. Not until the production had to be reduced, were Japanese and American managers capable of noticing significant outcomes that Toyota had achieved” (Dekier, 2012, p. 47). Ramezani & Mahdloo (2014) have described Lean Thinking as “an attitude to increase productivity, sustained value creation and minimum cost and waste.” (p. 37).

Lean construction which is the adaptation of Lean thinking principles in the construction context, can be defined as “a way to design production systems to minimize

waste of materials, time, and effort to generate the maximum possible amount of value.” (Rajab, 2022, p. 4). Not only does it focus on continuous improvement, efficiency enhancement, and eliminating non-value-adding activities, it extends beyond these lean principles according to Kifokeris and Koch (2023) including other practices such as, Last Planner System (LPS), Just In Time (JIT), and lastly Integrated Project Delivery (IPD). This comes from its understanding and focusing on customer needs, “Lean approach is an outcome of manufacturing leaders acknowledging the importance of customers’ satisfaction and the necessity of responding rapidly towards customers’ needs” (A, 2015, p. 1).

Likewise, the collaboration and communication between clients and architects is vital to the project’s outcomes, since architectural design is a process that is primarily driven by client requirements. Just as lean practices, focuses on responding to customer needs, architecture relies on continuous communication and feedback, to ensure that the final product meets the client’s expectations.

In architecture, specifically in the architectural design process, lean practices can be implemented to improve design workflows, increase collaboration, and eliminate waste. While traditional architectural design follows a linear approach, Hettithanthri et al. (2022, p.5) noted that “even though the architectural design process has several iterations in between, it has shown a linear approach in accommodating the point of view of the stakeholders”. Lean principles challenge this conventional workflow, by emphasizing an iterative process that is led by a feedback system, where problems are identified and resolved in the early designing stages, unlike traditional architectural design process where inefficiencies may become evident in later stages of construction.

Ries (2011) in his book “The lean start up” supports this approach, as he explains that iterative development allows for continuous learning and adaptation, ensuring that adjustments are made early before they become expensive or disruptive. In architectural design this approach allows not only architects but other related parties, like civil, mechanic, and electric engineers, to refine their work through early feedback, resulting in a more efficient and client centred outcomes.

As stated by Sharma and Khatri (2021) there are eight types of waste in lean thinking, defects, overproduction, waiting, non-utilized talent, transportation, inventory, motion, and extra processing, these types of wastes are also present in architectural processes. These problems often come from miscommunication, lack of coordination between involved parties, and unnecessary revisions (Ries, 2011). By utilizing lean principles within the architectural design process, specialists can enhance the efficiency of workflow, improve decision-making, and make sure each design activity adds value to the project by reducing non-value-added tasks promoting early problem solving (Marzouk et al., 2011).

However, studies in developing countries such as Palestine have highlighted the challenges that encounters the implementation of Lean such as limited awareness, resistance to change, and lack of training (Enshassi & AbuHamra, 2017). Sbeih (2024) and Albatsh (2015) in their studies explain how lean practices are underutilized because firms in Palestine prefer to stick to traditional project delivery methods and have limited exposure to Lean within construction and education systems.

2.3 Building Information Modeling (BIM)

Building Information Modeling (BIM) a digital tool that has transformed the construction industry, by providing an advanced platform that incorporates multiple processes throughout the projects' lifecycle. BIM is not only limited to architecture, it can be used in engineering, construction, mechanical, electrical and so on, it is used for designing, planning, operating, budgeting, detailing, forecasting... etc.

Olaiya et al. (2024) have defined BIM as “The term “Building Information Modeling” (BIM) is most commonly used to describe a collection of parametric tools and processes for the creation and upkeep of an integrated collaborative database of multi-dimensional information about the planning, construction, and operating of a building.” (p. 2).” It is important to highlight that BIM is not just a 3D program it is more than that. As Andrea (2022) stated, “BIM is not just a software; it is a process and software.”

BIM contributes to increasing efficiency by reducing errors, improving accuracy, minimizing the time and effort spent on repetitive tasks, and optimizing workflows.

Akinradewo et al. (2023) stated that “The use of Building Information Modelling (BIM) is critical to the success of today's project delivery methods.”

As Khattra and Jain (2024) explain:

BIM is transforming the way buildings and infrastructure are designed, constructed and managed by leveraging digital technologies to improve efficiency, collaboration and decision-making, across the entire lifecycle of a project. In essence, BIM transforms traditional building design and construction processes by leveraging digital technologies to create a comprehensive and coordinated approach to building project management and lifecycle maintenance. It enhances efficiency, reduces costs

and improves the quality and sustainability of buildings and the overall quality of building projects from conception to operation. (p. 147).

Beyond the basic and general definition of BIM, it's usually described by its maturity levels. These levels reflect how well BIM is applied and how well information is shared, organized, and how well data is being managed. In research BIM maturity level are from 0-3, "The BIM maturity levels can scale from level 0 to level 3 and beyond" (Gimenez et al., 2025), Alankarage et al. (2022) have revealed how these levels can extend up to ten, in their study they have mentioned and defined the five most common levels of BIM maturity which are as follows:

1. **Initial** (Level 0): No BIM strategy, Information is shared separately and drawings are 2D produced by Computer Aided Design (CAD).
2. **Managed** (Level 1): Familiar with BIM implementation with available basic guidelines, yet, a clear lack of BIM knowledge and skills.
3. **Defined** (Level 2): the implementation and processes of BIM are known and understood by most, with a detailed plan and an advanced collaboration.
4. **Measured** (Level 3): "Fully integration of BIM with strategic, organizational, communicational, and managerial channels. BIM performance benchmarks and standards are incorporated. Fully integrated building information models are available. Measurable quality targets are available." (Alankarage et al., 2022, p. 13).
5. **Optimized**: Full implementation and integration of BIM from the software to the processes, where they are being monitored and revised, "Actively achieved BIM vision." (Alankarage et al., 2022, p. 13).

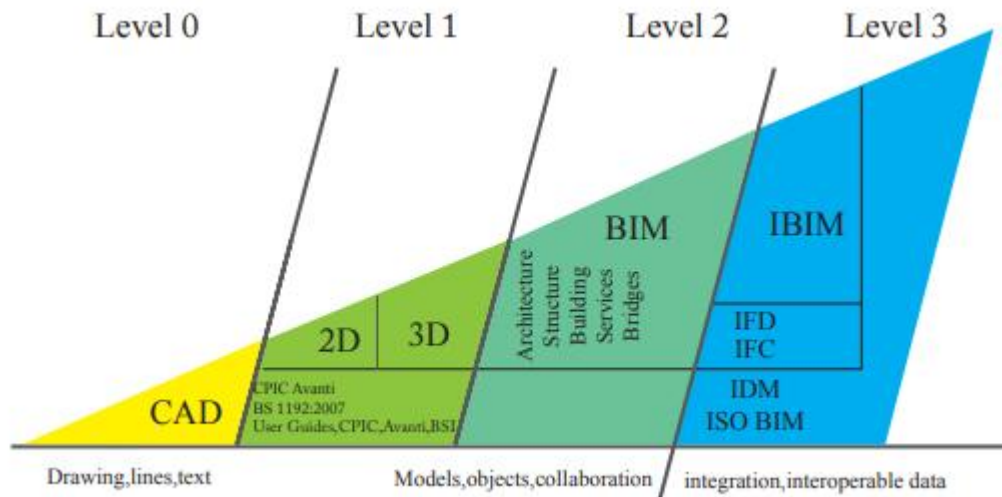


Figure 2.1 BIM Maturity Levels: Adapted from “*Building Information Modeling (BIM) in Enhancing the Applying of Knowledge Areas in the Architecture, Engineering and Construction (AEC) Industry*” by M. N. Maliha, B. A. Tayeh, & Y. I. Abu Aisheh, *The Open Civil Engineering Journal*, 14(1), 388–401 (2020). <https://doi.org/10.2174/1874149502014010388>

As shown in Figure 2.1 BIM Maturity Levels reflect different stages of digital adoption. This separation of levels helps to understand each countries BIM maturity level, where Palestine lies within the Level 0–1, as it has a low level of adoption and implementation of BIM (Maliha et al., 2020). Even in developed countries BIM is not yet at its highest levels. Studies show that many developing country industries remain around level 0-1 (Adetoro et al., 2025). According to BibLus (2025) the UK have not yet reached level 3 of maturity, the country is still at level 2, demonstrating how BIM maturity is a gradual process, that requires digital, technological, and most importantly cultural adaptation.

While these levels show the maturity level of BIM, growth, and overall use in construction, BIM’s biggest influence can be seen in architecture, as its mostly used by

specialists in this field, and this is where BIM happened to make the most changes in the design process and how professionals collaborate, transforming the way they work together.

Building Information Modeling (BIM) changed the future of architecture and architectural design process, as it offered an advanced digital platform that integrated the different architectural process in one place.

According to Yang and Liao (2016):

Generalized definition: BIM is a cloud computing and data technology and visualization technology of database based, integration and management of the construction project life cycle related geometry information and non-geometry information, project planning, design, construction, operation, and maintenance provide bearing information and support. (p. 2).

The implementation of BIM in the architectural design process has reduced errors, improved accuracy, optimized workflows, reduced the time and effort spent working on standard details regarding the different building components. “The architects can be arbitrary output plane, elevation and details of various detail, building materials, doors, windows, tables, you can also output the budget report, the construction schedule sheets and so on.” (Yang & Liao, 2016, p. 3).

BIM has helped to facilitate the whole construction process, enabling engineers and architects to collaborate effectively and efficiently in a shared environment. BIM’s greatest advantage is that it offers and facilitates a real-time collaboration, unlike the traditional software architects use for the design process like Computer-Aided Design (CAD), where 2D and 3D drawings are in isolation, files have to be shared manually through emails. BIM

provides a smart and data rich model that allows the collaboration amongst professionals from various fields.

As Shewale et al. (2023) highlight, “With the adoption of BIM, the time spend on coordination is reduced enabling the engineers to focus on solving problems instead of manually checking for errors.” (p. 3). Similarly, Abdalhameed and Naimi (2023) explained that “Using on the BIM methodology is useful in increasing cooperation between different design groups and helps reduce errors if each group works alone without sharing information with other groups.” (p. 240).

The highly beneficial features of BIM align with lean principles, both strive to enhance efficiency, reduce waste, and streamline workflows in the various construction processes. Moreover, similar to the lean tools, BIM supports clash detection, which is a tool that is concerned with detecting conflicts and errors in the project’s model. Abdalhameed & Naimi (2023) emphasized that “this technique can detect all existing clashes in the drawings of all disciplines before proceeding with the implementation process.” (p. 240).

Furthermore, they explained:

This tool helps in identifying and discovering collisions and overlaps between the components of the building, if they are found in the designs, and exporting a report about them and solving them, and this reduces the need to review and modify designs during construction, and for this it will control both the time and cost of the project. (p. 244).

By incorporating BIM, lean principles such as “right the first time” and “minimizing rework” can be successfully achieved.

Despite these advantages, BIM is still unfamiliar in developing countries like Palestine, as it's still in its early adoption stages. This is due to many limiting factors as stated by Sbeih (2024) from the cost of software and adoption, lack of training, lack of skills and awareness. Enshassi and AbuHamra (2017) in their research outline how there's a gap in skills between specialists, as architects in their education journey do learn about BIM, but other engineers (Electric, Mechanic, and civil) may not be exposed to it, this creates difficulties in interdisciplinary collaboration which is vital for the successful delivery of projects.

While most literature focused on the adoption of BIM and its importance, "using BIM is considered a competitive advantage for companies. BIM can be used at all stages of the project lifecycle, including design, construction, operation, and maintenance." (Samimpay & Saghatforoush, 2020, p. 127), recent literature has matured, including more than the adoption of BIM in an organization, it highlights BIM's outcomes, such as efficiency, innovation, and sustainability. Tiza et al. (2024) mentioned in their research that "Building Information Models (BIM) have been helpful in the construction industry because they put all the information about a project into one digital model and make it easier for the different people working on it to talk to each other and work together." (p. 1).

In their research Al-Zubaidi and AlZaidi (2025) discuss the importance of BIM adoption in organizations particularly in the construction sector, and especially when BIM is paired with Lean according to the results they have gained from analyzing various data, "The collected data, analyzed through quantitative regression models and qualitative thematic analysis, provide substantial evidence supporting the hypothesis that BIM-Lean synergy enhances construction project deliver." (Al-Zubaidi & AlZaidi, 2025, p. 559).

The integration of BIM-Lean has consistently shown its beneficial values across several empirical studies, “A study in Sweden revealed that Lean and BIM integration during the design phase of projects have many advantages including: transparency, easy cooperation, the involvement of project information between all stakeholders, and a reduction in project waste.” (Al-Adwani, 2022, p. 89). Demonstrating how BIM-Lean is getting more sophisticated over time.

In the Middle East, there is still many restrictions and barriers on the implementation of BIM itself and BIM-Lean, these include the cost of implementation, the lack of specialists, and the lack of skilled personnel (Al-Adwani, 2022). In Palestine specifically, in the construction sector, BIM adoption is still in its early stages, the lack of awareness, insufficient knowledge, and financial challenges, are some of many restrictions that are hindering the progress of BIM adoption in Palestine, in their research Saleh and Bakri (2021) explain how the implementation of BIM in Palestine is incomplete:

Furthermore, the lifecycle of BIM implementation is incomplete as, mostly, the contractor doesn't use BIM model. A part of this, firm No 2 pointed out that according to practice in Palestine for the private small and medium project, the equipment of the mechanical and electrical design in terms of its specifications are chosen by the contractor at the construction stage which make building a BIM model at the design stage is a complicated and useless process. (p. 4).

This only reinforces the need to fit BIM in the Palestinian construction context, in a way that suits it given its various complicated challenged especially the ones related to efficiency and coordination.

2.4 BIM-Lean integration

The integration of BIM and lean practices has become a popular strategy, that facilitates the improvement of efficiency and sustainability.” Interactions between Lean and BIM have increased over time, possibly thanks to BIM diffusion and the development of technologies and innovations in this field of knowledge.” (Landim et al., 2022, p. 620). In their research Hattab and Hamzeh (2015), have elaborated on the fact that BIM and lean are synergistic practices, BIM could be considered as one of lean tools as it works to achieve its goals, enabling real time management, and improving decision making.

Building Information Modeling supports achieving lean goals with its data driven system, as every decision is based on real-time information and analysis. Based on Sacks et al. (2010), there are many areas where BIM and lean overlap, as they have used a matrix of 56 identified interactions, almost all of the interactions were constructive and not conflicting. Some of these include:

1. Enhancing collaboration and workflow

Multi-disciplinary collaboration in BIM allows different involved parties from architects, and engineers to work on a single, integrated model. In alignment with lean principles this enables smoother workflows and reduces waste, and overproduction. According to Sacks et al. (2010), collaboration in design happens in two ways, internally and externally. “Internally, where multiple users within a single organization or discipline edit the same model simultaneously, and ‘externally’, where multiple modelers simultaneously view merged or separate multi discipline models for design coordination.” (Sacks et at., 2010, p. 11).

2. Improving designing, planning processes, project management, and decision making.

As stated by Sacks et al. (2010) Building Information Modeling enhances the expected results from lean practices, as lean promotes the early engagement of stakeholders, and value driven design. BIM tools such as its predictive analysis tool allows it to conduct a feasibility study on the project before implementation, this is an important step that can be done in early stages with the help of BIM. It provides stakeholders with the needed insights to make the best decisions for the project to ensure its success.

The speed of which the design can be conducted with the help of BIM resolves many problems that architects face, especially in the early stages of design, from client requirements, designing style, site analysis, and construction matters. This allows for a more efficient planning process, “changes to plans can be made and evaluated within hours” (Sacks et al., 2010, p. 11). It also leads to an improved design, with the rapid generation of multiple design alternatives that BIM offers.

Lean focuses on the concept of Gemba (Go and See), “A Gemba walk or regular workshop visits are one of the best practices for identifying company issues” (Micieta et al., 2021, p. 605). BIM enhances Gemba with its ability to provide virtual site walkthroughs, these virtual walks save effort, time, and cost, improving project management and control. BIM capabilities like visualization, makes it easier to do quality control checks regularly ensuring that the project,

from plans, and designs meet the specifications and requirements, from client requirements and regulatory ones.

3. Variability reduction in design and construction

Most of Lean tools goal is to reduce variability in production, concepts like “Right, first time” is inherently supported by BIM, as it enables design validation, clash detection, and simulation, before the actual construction begins. This reduces errors, reworks, and variability, BIM ensures that before reaching the implementation phase the project as a whole is accurate, coordinated, and optimized.

Moreover, BIM enables real-time information sharing, which minimizes the risk of miscommunication and inconsistent design updates. This also allows for early meetings with clients to work on adjustments, reducing the risk of having last minute changes. One of BIM tools used is the Automated quantity take-off, this tool ensures accurate material estimation, reducing waste and uncertainty in procurement. (Sacks et al., 2010).

4. Reducing waste and increasing efficiency

As stated by Sharma and Khatri (2021) the main goal of lean is to eliminate waste, including defects, overproduction, waiting, non-utilized talents, transportation, inventory, motion, and extra processing. BIM facilitates the way those results are obtained, by providing a real-time status update system, this provides the materials and productions schedules, ensuring Just-In-Time deliveries.

In addition to that, its computer-controlled fabrication reduces human errors and material waste, with a fully detailed virtual model, it eliminates the need for a physical prototype, as the virtual model is more accurate. “All BIM systems provide the ability to render the designs with some degree of realism, making building designs more accessible to non-technical project participants and stakeholders than is possible with technical drawings. (Sacks et al., 2010, p.10).

Literature highlights the synergy between Lean and Building Information Modeling, emphasizing the enhanced lean results gained by utilizing BIM, presenting a transformative approach that facilitates and improves efficiency, reduces waste, and fosters effective collaboration. However, as shown in many studies this synergy is not without limitations, which researches such as Hattab and Hamzeh (2015) and Landim et al. (2022) confirm the importance and value of BIM-Lean integration, other studies like Fasasi (2024) and Sbeih (2024), underscore the obstacles that come along, from organizational resistance, technical complexities, limited managerial support, to cultural and legal.

This synergy is illustrated in various cases, one of the notable examples in practice is documented by Bhatla and Leite (2012) where they studied a major renovation project at the University of Texas at Austin “The Lee and Joe Jamail Swimming Centre”, in this case study BIM was implemented along with Last Planner system which is a lean construction tool, in this study it was explain how this integration helped to significantly enhance collaboration, efficiency, coordination, and reduce uncertainties, a 50% reduction in request for information (RFIs) was recorded in the study, and fewer changes were required due to these enhancements.

Another example of BIM-Lean integration is the case study of a modular data centre project in Dublin, Ireland by McHugh et al. (2019) where they showcase the BIM merging with Lean planning methodologies, where VisiLean and Last Planner system were utilized alongside BIM to facilitate real-time visualization, collaboration, and continuous improvement of the project. A final example of the BIM-Lean integration is the Dezhou, China case study by Hei et al. (2024), in this study they investigated BIM-Lean integration in a building disassembly and reuse project, where it was found that this approach significantly enhanced material reuse rates, optimized labour coordination, and improved the environmental outcomes.

Although there is a lot of research that supports the integration of BIM and Lean, showcasing its advantages and enhancements, in reality there are many challenges that companies may face trying to implement BIM. “These challenges include resistance to change, traditional construction methods, workflow changes, lack of top management support, and undervaluing BIM” (Fasasi, 2024, p. 19).

2.5 BIM-Lean integration the Palestinian context

In Palestine, these challenges are even more pronounced and include, laws and rules engineering and architectural offices must obey, standardization as there are no unified BIM standards or guidelines, implementation complexity, and lastly the most important challenge that offices face is the lack of skill and proficiency in BIM among professionals outside of the architectural domain (Albatsh, 2015; Sbeih, 2024).

As stated by Sbeih (2024) while architects train during school to use such tools and gain the skills for it, most engineers like electrical, mechanical, and civil engineers are not familiar with it, or have limited experience with the software, if they have had training in it

at all. This gap in skills between disciplines can create a barrier to an effective and seamless collaboration, as BIM requires collaboration across different fields.

The studies that have been made on BIM-Lean integration in Palestine are scarce, and the few that exist often focus on each one of those separately rather than together. The small number of studies conducted on BIM-Lean integration demonstrate how BIM-Lean is a strategic direction for improving project delivery. Sbeih's (2024) study titled "Strategic planning to improve the construction industry in Palestine: Towards BIM and Lean in Palestine." Has presented a frame for adopting BIM and Lean in Palestine, by highlighting the need for clear standards, institutional support, and coordinated building skills, instead of relying on fragmented adoption.

This review of the local context highlights why the Palestinian AEC industry is in dire need for a combined digital and management approach, an approach that is tailored to it. The current situation of a low BIM development along with a limited use of BIM methods, underscores a major gap in both literature and practice. With a proper research and study of these systems and how they work together, technically and organizationally, it can lead to strategies that fit the local context not just the Palestinian context but underdeveloped or third world countries, improving efficiency, creativity, and most importantly teamwork.

2.6 Relationship between Variables

1. BIM-Lean integration and Design Coordination (DC)

The integration of BIM and Lean significantly enhances Design Coordination (DC), as BIM is used for clash detection and visualization (Toochukwu, 2025), whilst applying Lean to help structure planning and reduce waste. Figure 2.2, presents the Last Planner System's; which is one of Lean construction tools; role in the construction process,

including architectural design process. The figure shows how LPS focuses on teamwork, communication, clear and structured planning, commitment, and workflow stability, which all lead to reducing design inconsistencies and improves collaboration and coordination among projects' stakeholders. This together with BIM and its clash detection and visual abilities substantially enhances the coordination amongst architects, engineers, and even contractors (Bhatla & Leite, 2012; Abdalhameed & Naimi, 2023). This relationship is deemed to be vital, since poor coordination between professionals leads to reworks and project delays.

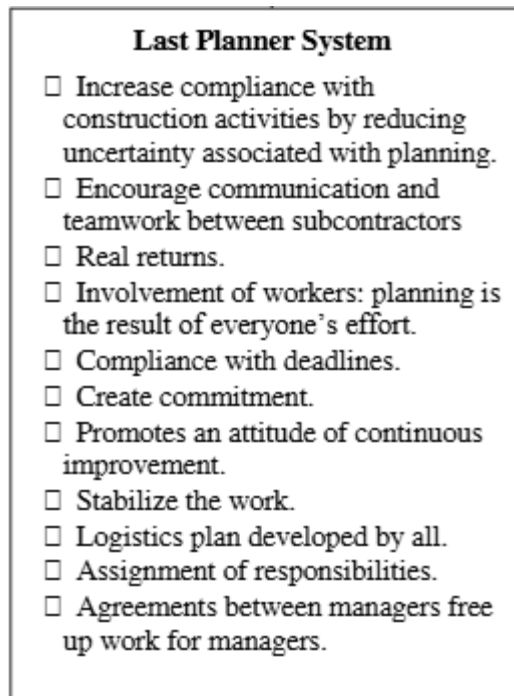


Figure 2.2: Key Elements of the Last Planner System (LPS)

Note. Adapted from *A Review on Lean Construction for Construction Project Management* (p. 46), by Garcés, G., & Peña, C. (2023), *Revista Ingeniería de Construcción*, 38(1), 43–60.

<https://doi.org/10.7764/RIC.00051.21>

2. BIM-Lean integration and Information Flow Quality (IFQ)

BIM-Lean integration according to literature enhance information flow. BIM acts as a model that provides real time data sharing “centralizing project data into a single, accessible model, ensuring that all stakeholders work from the same information” (Toochukwu, 2025), while Lean ensures structured communication and just in time (JIT) information delivery. This combination of BIM-Lean minimizes delays, reworks, errors, improves accuracy, and reduces fragmentation, which are caused by information bottlenecks, and isolated data flows (Evans & Farrell, 2020).

Information flow quality is vital especially in countries like Palestine where projects mostly suffer from inefficiencies due to the lack of information sharing or the late exchange of data. Moreover, BIM enables documentation of the project from start to finish, structured planning, and compliance tracking as a part of the execution workflow (El Mounla et al., 2025), BIM-Lean establishes a solid foundation for precise, accurate, and timely exchange of projects’ information.

3. BIM-Lean integration and Collaborative Workflow (CW)

Collaborative workflow is directly benefiting from BIM-Lean. As BIM fosters transparency and IFQ, furthermore, one of the core principles of BIM according to Toochukwu (2025) is Interoperability “This capability supports smooth workflows and enhances project efficiency, particularly in complex, multi-disciplinary projects.” (p. 4349). This along with lean’s collaborative planning and continuous improvement practices leading to collaborative workflow and enhanced project outcomes.

Research such as Bayhan et al. (2022) and Shewale et al. (2023) empirical studies demonstrate how this synergy promotes collaborative practices across diverse teams leading

to enhanced workflow efficiency and optimized processes. In the architectural design process, collaboration workflow is vital since professionals need to communicate effectively and provide contribution of expertise that is sometimes overlapping, within multidisciplinary teams.

4. Design Coordination (DC) and Efficiency Enhancement (EE)

Design Coordination leads to EE, by resolving conflicts and errors in the early stages of the project, this minimizes delays and reworks in the construction process. With BIM-Lean strengthening this connection, lean emphasizes “Right first time” principles and BIM detects clashes and mistakes in the early stages of the project (Abdalhameed & Naimi, 2023). Literature demonstrates how projects that have a strong design coordination practices reach higher efficiency levels in terms of time and cost savings.

In the architectural design process DC is very essential, because multidisciplinary specialists must integrate their inputs seamlessly in order to avoid fragmentation and inefficiencies. BIM-Lean integration is the core of this whole framework “Integrating BIM and lean paradigms in a public construction project at the University of Alicante reduced architectural conflicts and improved coordination” (Likita et al., 2025).

5. Information Flow Quality (IFQ) and Efficiency Enhancement (EE)

By ensuring that project’s stakeholders work with accurate, timely, and complete data, IFQ leads to EE. Lean focusing on eliminating waste such as waiting; when teams can’t proceed with work due to missing inputs; or rework; when tasks are redone many times due to missing, inaccurate, or incomplete information; and BIM’s role of real-time information sharing and updating in one precise and consistent model where stakeholders

have access to project data (Nguyen, 2025). BIM-Lean improves planning, communication, leads to smoother processes, and an overall enhancement of efficiency.

6. Collaborative Workflow (CW) and Collaborative Effectiveness (CE)

CW has a direct impact on CE. When workflows are transparent, well organized, and inclusive, collaboration becomes stronger, meaningful, and more productive (Too-chukwu, 2025). Lean approaches encourages team-based problem solving instead of each discipline working in isolation, this helps to build responsibility and avoid blame-shifting (Klein et al., 2022), while BIM provides the platform where they can visualize problems and solutions in real time (Fernandes et al., 2024).

When BIM and lean are used together, teams have both the technology, process, and methodology needed for strong collaboration, moreover, decision making is improved since everyone sees the same model and contributes to solutions. Many studies explain how this integration leads to better collaboration, decisions, and a higher project effectiveness.

2.7 Gap in the Literature

The integration of BIM and Lean, represents a transformative shift in construction, engineering, and architectural fields. By utilizing BIM to obtain improved results of lean practices, gaining better efficiency, enhanced collaboration, and cost effectiveness. This highlights the need for a localized research, especially in developing countries such as Palestine, where the cultural, economic, and regulatory challenges differ from the developed countries. Despite the proven benefits of BIM and Lean construction applied separate and/or together, there are still several gaps in the literature.

In particular there is limited research in underdeveloped areas, the integration of BIM-Lean is still relatively underexplored in developing countries, especially in the Middle

East. Most of the research conducted has concentrated on first world countries such as the United Kingdom, Sweden, and the United states, where in these countries the BIM's maturity levels reach level 2 (BibLus, 2025; Adetoro et al., 2025).

While in countries like Palestine, BIM and Lean (separately) are still in their early stages of adoption. Studies conducted on BIM in Palestine have revealed that its implementation is highly fragmented, both in the construction industry and in academia (Enshassi et al., 2016). According to Al Daoor (2021) in his research conducted in Gaza strip, Palestine:

22% of respondents believe that the lack of experts in this field was one of the reasons for not adopting BIM as a course in Palestinian Universities, while 17% believed that it was due to lack of educational resources, weak knowledge of the benefits of BIM, and needs high programs and possibilities not available in the universities. Also, 14% believed that it was due to the lack of communication between academic institutions and the construction industry, while 11% believed that it was due to considering it as a modern technology, and 2% believed that it was due to another reasons. (p. 219).

Similar to BIM, Lean practices are also underutilized in Palestine especially in the construction industry, as most firms prefer traditional methods over new methodologies such as Lean (Enshassi & AbuHamra, 2017). While these studies have explored the barriers and limitation to BIM and Lean individually, there is very limited empirical research that investigates their integration in the construction industry in Palestine.

Regional research such as the study done by Musharavati (2023) on the integration of BIM and Lean construction in Qatar, and the study done by Al-Adwani (2022) on the

development on BIM-Lean process in the construction industry in Kuwait, have noted how these countries in the Middle East have taken the first steps in advancing BIM and Lean adoption. Yet, this adoption is still uneven and faces a lot of challenges, making the need for localized research in areas like Palestine even more urgent, since relying on evidence from more advanced regional cases can't fully capture the unique conditions of the Palestinian construction industry.

Moreover, there is a lack of theoretical models that test the mediating role of Collaborative Workflow, Information Flow Quality, and Design Coordination, and how they link BIM-Lean integration to Efficiency Enhancement and Collaborative Effectiveness. In addition to that, organizational agility have shown to be one of the mediators between digital transformation and innovation capability according to the literature (Bennett et al., 2025); however, this role have not yet been explored within the BIM-Lean context, and it presents an opportunity for future research.

Alnajjar et al. (2025) in their research demonstrate how while BIM-Lean technology integration has many documented benefits, there is still a gap in the theoretical models that explain the mediating mechanisms. "The findings emphasize the need for cohesive frameworks that bridge theoretical exploration with empirical validation." (Alnajjar et al., 2025, Discussion, para. 3).

This gap in literature highlights the need for a research that does not only explore the benefits and potential of BIM-Lean in Palestine, but also delves in how it leads to Enhanced Efficiency (EE), and Collaborative Effectiveness (CE), with Collaborative Workflow (CW), with Information Flow Quality (IFQ), and Design Coordination (DC) mediating this relationship. Recent study by Alnajjar et al. (2025) has emphasized this, underscoring the

lack of theoretical models that explain how these effects occur, what or which processes cause them. Similarly, Bennett et al. (2025) highlights the importance of identifying mediating capabilities that connect digital and technological transformation with measurable performance outcomes.

While the findings of this study are expected to benefit the construction industry as a whole, the research specifically focusses on the architectural design process. Where the previously mentioned variables are most critical. By addressing this gap, the research provides theoretical and practical insights that benefit professionals in the construction industry in Palestine by enhancing project delivery.

As stated by El Mounla et al. (2024), BIM-Lean integration, particularly during the design phase, enhances coordination and project outcomes. The findings of El Mounla et al. (2024) study underline the importance of early collaboration between stakeholders, engineers, and architect. This facilitates better communication, resulting in better outcomes, reducing delays, misunderstandings, conflicts, and much more, which all collectively lead to the enhancement of overall efficiency.

2.8 Conceptual Framework

The conceptual model below is a representation of the relationships that the study proposes, it identifies BIM-Lean integration as the independent variable that impacts the project outcomes in the architectural design process. This framework is based on the idea that the integration of Building Information Modeling (BIM) and Lean principles

significantly improves the projects efficiency, the full impact of that integration is often mediated by certain factors as illustrated in Figure 2.3.

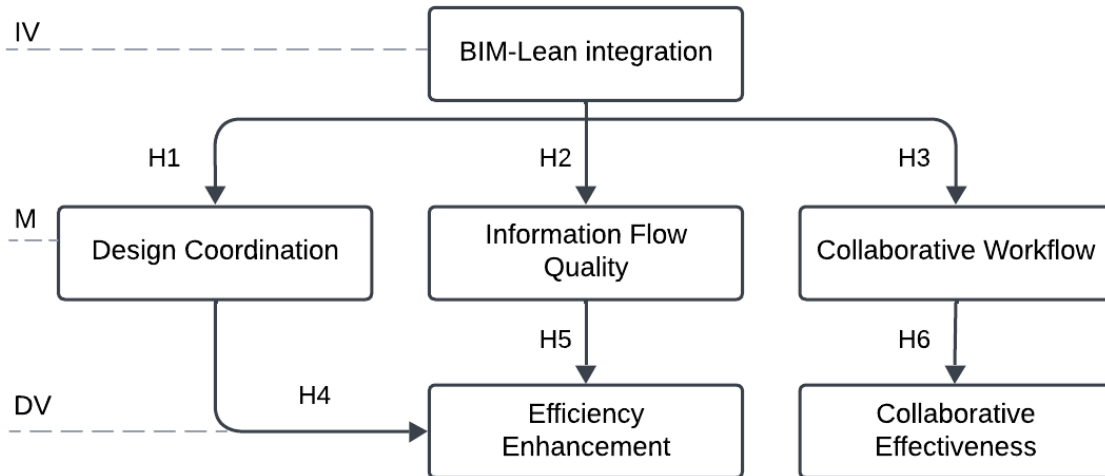


Figure 2.3: Conceptual model

Figure 2.3 illustrates:

- **BIM-Lean integration as the Independent Variable (IV)**
- **Mediating variables (M)**
 - 1) **Design coordination (DC):** “design coordination involves harmonizing the various design inputs from different project stakeholders – architects, structural engineers, MEP engineers, and other specialists. Each discipline contributes a crucial piece to the overall puzzle, and without effective coordination, these pieces can clash, leading to costly rework, delays, and compromised quality on-site” (Catenda, 2025). DC helps in identifying and resolving defects and conflicts in the early stages of the design process.
 - 2) **Information flow quality (IFQ):** which is the core element to better communication, “The giving out and receiving of information is the

elementary objective of all kinds of communication” (Giarette et al., 2017). IFQ is the accessibility, visibility, timely, and accuracy of the shared data and models between departments.

3) **Collaborative Workflow (CW)**: “collaborative workflows involve collaborative intellectual problem solving, leveraging expertise and judgement from multiple stakeholders.” (Deokar et al., 2008). It also means the degree of a real-time collaboration between stakeholders such as Engineers and Architects where they work on a shared set of tasks.

- **Dependent Variables (DV)**

- 1) **Efficiency Enhancement**: which can be achieved when the classified Lean wastes are dealt with “motion, excess processing, defects, overproduction, waiting time, underutilization of talent, transportation, and excess inventory. Lots of wastes are generated in the construction industry.” (Shabeen & Jemimah, 2024). “Lean principles and BIM platforms contributed in increasing project efficiency, reducing project timelines and costs.” (Alwindawi, 2024).
- 2) **Collaborative Effectiveness**: how well interdisciplinary teams work together to achieve set objectives. Collaboration is identified as “a type of interaction in which individuals, or team or organizational members, work together to reach a common shared goal, activity or production.” (Keyton, 2017).

2.9 Chapter Summary

This chapter presented a comprehensive review of the literature that is relevant to the study's objectives. It discussed the ideas behind Lean Construction and Building Information Modeling (BIM), describing their key principles, tools, and how they contribute to improving project performance. The chapter also included a review of researches that study the integration of BIM and Lean, demonstrating how this combination can improve efficiency, coordination, and teamwork, during design and construction processes.

This chapter shed some light on the Palestinian AEC industry, illustrating how both BIM and Lean are still not widely used due to various factors such as financial, educational, or even organizational challenges. This gap underscores how the local research needs to explore the integration of BIM and Lean due to its beneficial outcomes, from enhanced efficiency, collaboration, coordination, and more.

Finally, it identified the main relationships between the study's key concepts BIM-Lean integration, design coordination, information flow quality, collaborative workflow, efficiency enhancement and lastly collaborative effectiveness. It also introduced the conceptual framework that guides this study. The next chapter explains the research methods and research tools employed in this study.

Chapter Three: Research Methodology

3.1 Overview

This chapter presents the methodology that was adapted in this research in order to achieve the objectives and answer the questions of the study. The chapter starts by explaining the philosophical foundation of the research, then dives into the research design, approach, strategy, data collection methods, sampling techniques, and the analytical procedure that was employed to examine the integration of BIM-Lean within the AEC industry in Palestine specifically in the architectural process. Adopting a mixed method approach that is guided by a pragmatic research philosophy, ensures providing both measurable and contextual insights. Quantitative data were collected through a structured questionnaire, while qualitative data were obtained through semi-structured interviews for a deeper understanding of the topic in the context of Palestine.

With the combination of these two methods, the chapter demonstrates how the study was carefully structured and designed to maintain validity, reliability, credibility, integrity, and guaranteed a comprehensive view of the study phenomenon.

3.2 Research Philosophy

The study's philosophy reflects the worldviews that direct how knowledge is formed and understood in the research process. In social sciences, major philosophies differ in how they define knowledge, view reality, and explain the relationship of the researcher with the phenomenon that is being studied. These philosophical perspectives guide the overall research design, how the research is structured, and how the results are understood within the contextual framework of the research.

This research follows a pragmatic philosophy, according to Elgeddawy and Abouraia (2024) pragmatism focuses on practical solutions to real-world problems, valuing both experience and facts; objective and subjective knowledge. As noted by Elgeddawy and Abouraia (2024):

Pragmatism emphasizes that we understand the world and solve its problems through the application of subjective and objective methods. Pragmatist researchers are flexible and practical in finding viable solutions to the phenomenon under inquiry. They recognize the importance of having multiplicity of perspectives and worldviews in solving research problems. Pragmatism derives pluralistic mixed methods research (MMR). (p. 71)

This philosophy not only aligns with the objectives and questions of the study, but it also helps to answer them best. The quantitative part of the study; a questionnaire survey; examines the measurable relationships between variables, while the qualitative part; semi-structured interviews; focuses on experience and factors that may have affection on BIM-Lean integration.

The use of pragmatic philosophy, allows the study to remain flexible, apply flexible methods, and focus on real-world practical solutions. This ensures that both the numerical and human experiences are considered, providing a comprehensive understanding of the integration of BIM-Lean, and its role in enhancing efficiency, and project's outcomes within the Palestinian context.

3.3 Research design

This section describes the overall methodological structure of the study, it explains how the adopted mixed method approach have been used in order to examine the research

objectives. The study utilizes both qualitative and quantitative methodologies, by combining these two methods the research seeks to achieve detailed knowledge about the integration of BIM-Lean in the architectural design process in Palestine, and its impact on the outcomes of projects.

The qualitative approach is used to gain an in-depth insight and understanding about the challenges architectural firm face trying to adopt BIM or Lean, their perspectives, and experiences regarding BIM and lean practices. While the quantitative approach is used to evaluate the current adoption rates, barriers, and potential benefits of BIM-Lean integration.

To analyse the extent of BIM and lean implementation and adoption, and to address the challenges that hinder their implementation in Palestine, a descriptive and exploratory research design will be used. Accordingly, the study adopts an explanatory sequential mixed-method design, where quantitative data collection and analysis are first conducted, then followed by qualitative data in order to explain and contextualize the quantitative results.

3.4 Research approach

This section explains the reasoning processes (deductive and inductive) that link the theoretical framework of the study to the data collection and analysis. Research approach outlines the process in which the theories and main ideas of the study are connected with the methods that are used to collect and analyze data, linking theory to practice. As stated by Luft et al. (2022) “These elements are important in shaping the construction of new knowledge. Theoretical frameworks offer a way to explain and interpret the studied phenomenon, while conceptual frameworks clarify assumptions about the studied phenomenon.” (p. 2).

Based on the research's objectives and questions, the study uses a mixed-method approach, both deductive and inductive reasoning. This aligns with the study's philosophy, as this pragmatic philosophy supports the utilization of multiple methods in order to explore or explain real world complexities. The deductive approach is used in the quantitative part of the study. As data were collected using a structured questionnaire then analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM). This technique using SmartPLS software aids in determining if the proposed relationships between variables are valid or not.

The inductive approach is used in the qualitative part of the study, the semi-structured interviews were conducted to explore the experiences and opinions of the professionals. This adds quality to the results as it identifies patterns, root causes, explain or add context to the quantitative results.

With the combination of both inductive and deductive reasoning, the mixed method approach ensures a comprehensive understanding of the research problem. While the deductive phase provides evidence to the suggested relationships between variables, the inductive approach gives insights into the contextual dimension of the BIM-Lean integration. Using these methods together strengthens the depth, accuracy, credibility of the study's conclusions.

3.5 Research Strategy

This section explains how the research design and approach were implemented in practice, highlighting the steps used to collect and analyse data. Demonstrating how the research design and approach were applied in order to establish the research objectives and

answer its question. The research follows a mixed-method approach that involves two main phases: a quantitative survey followed by qualitative interviews.

The first phase consists of an online questionnaire that was distributed by email through the Palestinian Engineers Association to professionals from architects, engineers, and other AEC practitioners across the major cities in Palestine. The survey collected numerical data on the adaptation and implementation of BIM and Lean practices in construction. It measured how BIM-Lean impacts projects, from efficiency, performance, collaboration, coordination, flow of information, and more. It also collected demographic information, including the years of experience, firm type, and familiarity with lean and/or BIM.

Phase two, semi-structured interviews were conducted with a selected few who had experience with both BIM and Lean. This stage aimed to gather insightful information about the challenges, benefits, and contextual factors that influence the BIM-Lean integration in the Palestinian AEC industry. This stage helps to explain and expand upon the findings from the first phase which only consists of quantitative data.

The combination of these two phases helps the research to achieve a complete understanding of the topic, by providing measurable results from survey and detailed contextual insights from interviews. This approach increases the credibility and consistency of the findings, giving a clearer picture of how BIM-Lean integration supports better project outcomes in the Palestinian context.

To enhance clarity and support a better understanding of the methodological structure, a visual flowchart has been constructed in order to show the connections between the qualitative and quantitative parts of the study. The flowchart explains how the pragmatic

philosophy shaped the mixed method approach, collection and analysis of data in each part.

The diagram provides a coherent representation of the research strategy as follows:

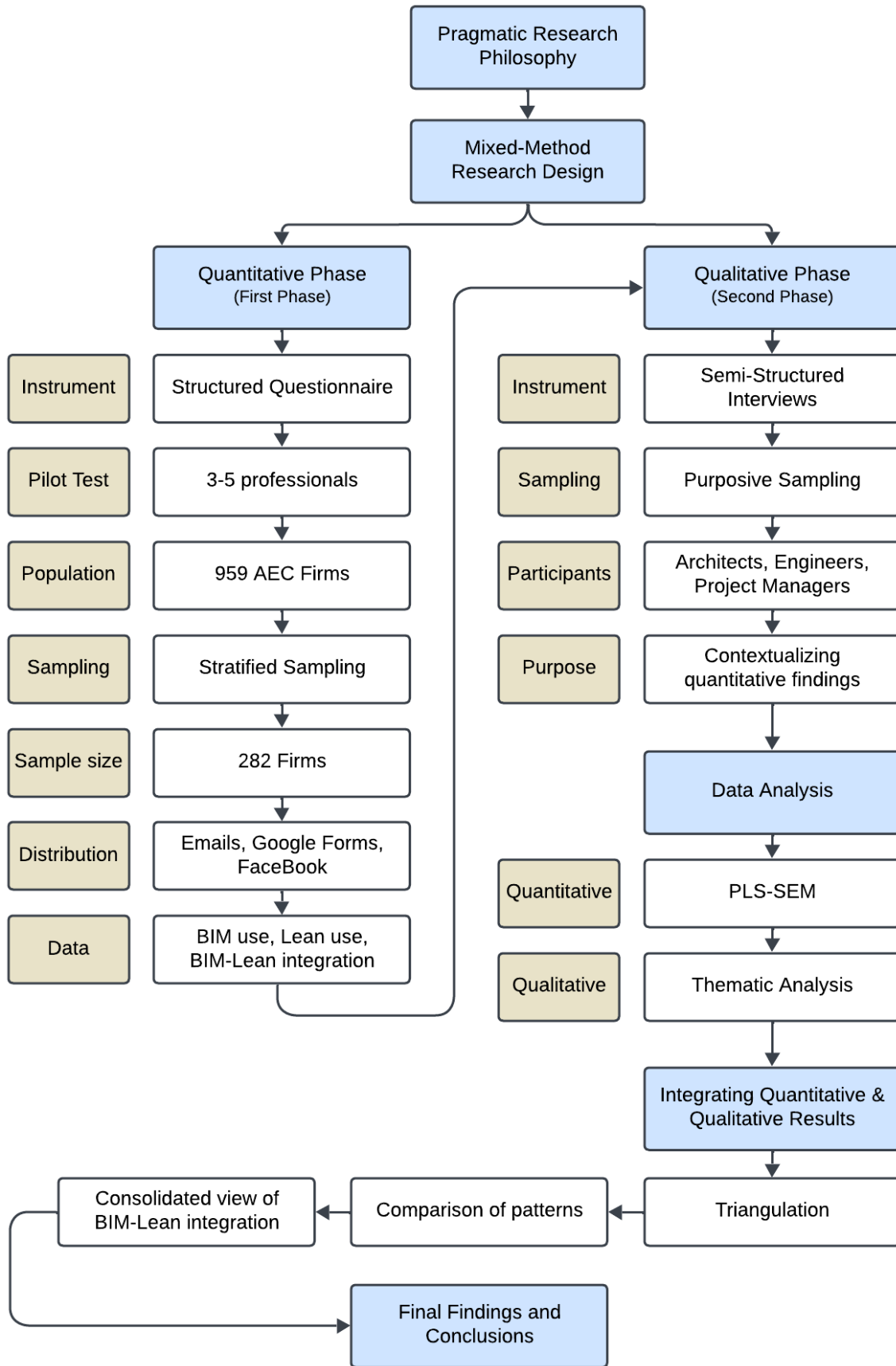


Figure 3.1 Research Methodology Flowchart

3.6 Research Instrument

There are two primary tools that have been used for data collection. For the quantitative phase, a structured questionnaire was selected since it's the most efficient and used method for collecting standardized data from larger population (Kuphanga, 2024). The research instrument was designed to capture both the quantitative and qualitative data that are aligned with the study's objectives.

3.6.1 Questionnaire Design

The formulated questionnaire consisted of five sections (see Appendix A):

Section 1. Consisted of demographic and professional information such as, years of experience, work place, firm type, position in firm, familiarity with Lean/BIM. These questions provide background variables in order to analyse the differences in adoption across groups.

Section 2. Focused on the application of BIM/Revit within organizations. In this section all constructs were measured with a 5-point Likert scale (1 being strongly disagree, 5 being strongly agree). This method was chosen because it has been regarded as a valid and reliable tool since its easy and simple to understand (Bodur et al., 2024).

Section 3. This section examines the adoption of Lean practices and its implementation. Similar to section 2 it used a 5-point Likert scale to evaluate constructs that relate to lean usage, collaboration, and outcomes. Questions in this section also focused on the impact of lean from rework and waste reduction to workflow and communication.

Section 4. This section investigates the BIM-Lean integration within organization. Similar to previous sections, 5-point Likert scale was used to measure constructs.

Collaboration, decision making, cost, scheduling, performance, and client satisfaction were examined in this section.

Section 5. The final section of the survey, an open-ended question allowing respondents to freely express their views on the main challenges or opportunities for BIM-Lean integration in Palestine.

The questionnaire constructs were developed according to items from previous studies that were examined in this research, studies on BIM, Lean, and the BIM-Lean integration to ensure strong content validity. Indicators that are related to BIM were developed with the help of studies such as Sacks et al. (2010), Enshassi & AbUHamra (2017), and Abdalhameed and Naimi (2023). Whereas, lean items were adopted from well-known studies; Dekier (2012), Garcés, & Peña (2023), and Moradi & Sormunen (2023). As for the indicators of BIM-Lean integration, these were developed based on models and frameworks from Hattab & Hamzeh (2015), Bayhan et al. (2022), and Alwindawi (2024). These sources guided the development of the measurement items used in the PLS-SEM analysis and ensured that the constructs were grounded in previous research.

3.6.2 Pilot Testing

Before questionnaires were distributed to the larger sample, the structured questionnaire was pilot tested with 3-5 professionals. This was conducted in order to ensure clarity and relevance of the survey. Pilot testing is important “A pilot study can present key information that can help guide the direction of the larger study or research project, including insights into the ultimate cost of the study, its overall feasibility, and any challenges that the actual study may face once it gets off the ground.” (Dovetails, 2023).

Based on the feedback, minor adjustments were made to the survey, to ensure that the time required to finish it was appropriate, questions are relevant to the topic, and lastly to ensure its overall clarity. In addition to the pilot test, the questionnaire was reviewed by experts to reinforce its content validity. Dr. Ashraf Almimi, Dr. Ibrahim Mahamid, and Dr. Sami Sader, three committee members who examined it for consistency, clarity, validity, and relevance to the topic. Their suggestions were taken into account and integrated in the final version before distribution.

3.7 Data Collection Methods

To guarantee a comprehensive analysis, the study employs both primary and secondary data resources. **Primary data includes:**

- **Qualitative phase (Interviews):** semi-structured interviews with 10-15 purposively selected participants, these interviews were made to gather data from architects, engineers, projects managers, and policymakers to attain all the beneficial insights about the BIM and Lean adoption and implementation challenges and opportunities in the architectural firms in Palestine. Interviews have been conducted face to face, or via Zoom meetings, recorded with consent for thematic analysis.
- **Quantitative phase (surveys):** questionnaires were distributed via Google forms, email, and Facebook groups to individual professionals working within the 959 registered firms which are identified by the Palestinian Engineers Association (2024), from architectural firms, engineering offices, construction companies, and contractors to collect data on BIM and Lean rates, from utilization, barriers, and industry perceptions. For maximized

responses, phone calls and reminder emails were sent two weeks after the initial distribution.

Secondary data includes collecting the needed information from previous researches, academic papers, industry reports, and case studies that relate to the topic of this study, the integration of BIM and lean principles, secondary data also includes the regulations and policies that affects the adoption of BIM and Lean in Palestine.

3.7.1 Contact Plan

In order to obtain reliable responses, a structured contact plan was made for reaching target audience through registered firms as contact access points. The plan outlines the time, procedures, and ways of contacting respondents in both the qualitative and quantitative phases.

- **Identification of respondents:** a list of 959 registered firms was obtained from the Palestinian Engineering Association (2024) as a contact source in order to reach individual professionals in the AEC industry. These firms were stratified by city to ensure geographic representation. Lastly, key contact persons from architects, engineers, and managers were identified using the Palestinian Engineering Association (2024), LinkedIn, Facebook, and other networks.
- **Initial contact:** an email sent to the address of each firm, this email explained the purpose of the study, confidentiality and anonymity assurance, and a link to the online questionnaire (google forms). Firms where emails were not available were contacted by phone.
- **Follow up:** 2 weeks after initial contact, reminders were sent to non-respondents, personal visits maybe conducted to larger firms in order to encourage participation.

- **Interviews:** based on the survey responses, 10-15 individual professionals with meaningful adoption of BIM or Lean are selected for interviews. These individuals were contacted by phone to schedule semi-structured interviews face to face or on Zoom, with proper consent forms.
- **Documentation:** all responses are on a tracking sheet, to confirm the response status (responded or not), how they were contacted, how long it took them to respond, and the date of contact. Moreover, weekly monitoring was conducted to ensure that the respond rates meet the target sample size of 282 responses.

3.8 Population and Sampling

3.8.1 Target Population

The study targeted professionals that work in the AEC industry from architects, engineers, and contractors across the major six cities in Palestine: Ramallah, Hebron, Nablus, Bethlehem, Jenin, and Tulkarm. These cities were chosen because they collectively account for 89% of all registered firms in the West bank according to the Palestinian Engineers Association (2024), with 959 active firms (see Appendix B).

Moreover, they host larger scale firms which make them more relevant for investigating and evaluating the implementation and impact of the BIM-Lean integration in the Palestinian AEC industry. The Palestinian Engineering Association list was mainly used as a sampling frame and a contact directory to reach individual professionals rather than a statistical definition of the study population.

3.8.2 Unit of Analysis

The unit of analysis in this study is the individual professional employed in the AEC industry in Palestine such as architects, engineers, and contractors. Although the sampling

frame was based on the list of the 959 registered firms in the Palestinian Engineering Association, this list was just used as a contact directory in order to reach individual practitioners.

While the main interest of the study lies within the organizational practices that are related to Building Information Modeling (BIM), these practices are examined through the personal experiences, knowledge, and perceptions of individual respondents, that engage with them in their work on a daily basis. Each of these participants represent a unit of analysis, this allows the identification of the differences in knowledge between these units, and aids to reveal the general trend in the AEC industry in Palestine.

3.8.3 Sampling Strategy

The study utilizes a mixed sampling strategy to ensure a comprehensive and reliable data collection. For the quantitative phase a stratified sampling method was used to ensure generalized findings and a fair geographic representation among architectural and engineering firms. As for the qualitative phase, a purposive sampling strategy was used to interview specific individuals, this helped identifying professionals that have meaningful experience in BIM and/or Lean adoption. Using this combination ensures depth in both the contextual and statistical insights and information.

3.8.4 Sampling Size Determination

For the quantitative survey, the sample size was calculated using Yamane's formula, with a 95% confidence level, and a 5% margin of error, the sample size calculated is approximately 282 individual respondents drawn from registered firms.

Yamane's formula:

$$n = \frac{N}{1 + N(e)^2}$$

Where:

n = sample size, N = population size, e = margin of error

In addition, since the study employs a Partial Least Squares Structural Equation Modeling (PLS-SEM), the sample size adequacy was cross checked using established PLS-SEM guidelines. The most common rule used for PLS-SEM is the “10-times rule” (Hair et al., 2014), “Which builds on the assumption that the sample size should be greater than 10 times the maximum number of inner or outer model links pointing at any latent variable in the model.” (Kock & Hadaya, 2018). In this study the maximum number of paths leading to any latent variable is three, so the minimum sample size following this rule should be 30 cases.

However, this method is not considered accurate “it has been shown in the past to lead to inaccurate estimates” (Kock & Hadaya, 2018). So, to be on the safe side, in order to ensure reliable and valid data, and to guarantee generalizability, the study has adopted the more conservative target of 282 responses. While this exceeds the PLS-SEM specific sampling, it ensures providing a more robust statistics that are more beneficial for hypothesis testing.

3.8.5 Qualitative Sampling

For the qualitative approach, a more of a criteria-based purposive sampling strategy was used. The sample for the qualitative method was determined after the findings of the quantitative sample have been analysed, this ensured that the selected sample is relevant, has meaningful adoption of BIM or Lean or both, with experience and real-life insights that can be helpful to the study.

A total of 10-15 interviews were conducted with a semi-structured interview (see appendix C) to achieve thematic saturation (Guest et al., 2020). This range is widely accepted in qualitative research, as saturation is typically reached within 6-12 interviews as stated by Guest et al. (2020). Which makes the number of interviews methodologically credible and sufficient sample size in order to obtain insightful and contextual information.

3.9 PLS-SEM Construct Measurement

This section describes the operationalization of all variables that are used in the PLS-SEM analysis, ensuring construct clarity and content validity. All variables are shown in Table 3.1 along with their indicators and theoretical sources that are derived from previous BIM, Lean, and BIM-Lean integration studies.

Each questionnaire item was assigned with an indicator code (e.g., BL1, BL2, DC1) to facilitate its use in the PLS-SEM analysis. Prefixes shown in the table below are defined as follows:

- **BL**, BIM-Lean Integration
- **DC**, Design Coordination
- **IFQ**, Information Flow Quality
- **CW**, Collaborative Workflow
- **EE**, Efficiency Enhancement
- **CE**, Collaborative Effectiveness

The numeric suffix following the prefix identifies the specific indicator within that construct, which allows SmartPLS to estimate the measurement model and structural relationships accurately.

Table 3.1 Measurement Constructs and Indicators

| Variable | Code | Indicator | Theoretical source |
|---------------------------------------|-------------|---|--|
| BIM-Lean integration (BL) (IV) | BL1 | Our organization actively uses BIM/Revit models to support lean planning practices such as Last Planner System. | Sacks et al. (2010) |
| | BL2 | Combining BIM-Lean improves coordination and reduces rework (Lean: meetings, continuous improvement, BIM: shared models and information). | Bayhan et al. (2022); Hattab & Hamzeh (2015) |
| | BL3 | Our organization plans to use BIM/Lean in the near future. | Alwindawi (2024); Sacks et al. (2010) |
| Design Coordination (DC) (M) | DC1 | BIM-Lean enhances decision making in the early stages of design and planning. | El Mounla et al. (2025); Sacks et al. (2010) |
| | DC2 | BIM-Lean contributes to better schedule performance. | Alwindawi (2024); McHugh et al. (2019) |
| | DC3 | BIM-Lean adoption improves safety (hazard identification through models). | Abdalhameed & Naimi (2023); Hattab & Hamzeh (2015) |

| | | | |
|---|-------------|---|--|
| Information Flow Quality (IFQ) (M) | IFQ1 | BIM-Lean enables timely, accurate, and reliable information flow across disciplines. | Giaretta et al. (2017); Sacks et al. (2010) |
| | IFQ2 | BIM/Revit Models are shared using common formats such as IFC for interchange to allow seamless collaboration and data exchange with other software. | Sacks et al. (2010) |
| | IFQ3 | BIM/Revit is used consistently across disciplines (Architecture, mechanical, electrical, structure) | Hattab & Hamzeh (2015); Sacks et al. (2010) |
| Collaborative Workflow (CW) (M) | CW1 | Management supports the adoption of BIM and Lean practices. | Evans & Farrell (2020); Moradi & Sormunen (2023) |
| | CW2 | Staff receive adequate training on BIM/Lean tools and methods. | Olaiya et al. (2024); Shewale et al. (2023) |
| | CW3 | Continuous improvement (Kaizen) is part of the organization's routine. (regular meetings to improve the firm's efficiency). | Dekier (2012); Moradi & Sormunen (2023) |

| | | | |
|--|------------|--|--|
| Efficiency Enhancement (EE) (DV) | EE1 | Integrating BIM-Lean reduces project time, effort, and material waste. | Alwindawi (2024); Sacks et al. (2010) |
| | EE2 | BIM/Revit reduces times spent on drawings such as plans, elevations, sections, details, and 3D models. | Samimpay & Saghatforoush (2020); Shewale et al. (2023) |
| | EE3 | BIM-Lean practices improve cost performance and reduce overruns. | Musharavati (2023); Samimpay & Saghatforoush (2020) |
| Collaborative Effectiveness (CE) (DV) | CE1 | BIM-Lean adoption increases overall client satisfaction. | Bennett et al. (2025); Musharavati (2023) |
| | CE2 | BIM-Lean promotes collaboration, transparency, and continuous improvement among teams. | Bayhan et al. (2022); Landim et al. (2022) |
| | CE3 | Employees are open to adopting new technologies and work methods. | Kudryavtseva et al. (2020); Liu (2024) |

3.10 Data analysis plan

For both of the qualitative and quantitative data to be analysed, different methods that align with each approach are used. Qualitative data collected from interviews are analysed using thematic analysis, in order to identify patterns and insights from the interview responses, this was done following Braun and Clarke's (2006) 6-step framework, "Phase 1: Familiarising yourself with your data, Phase 2: generating initial codes, Phase 3: searching for themes, Phase 4: reviewing themes, Phase 5: defining and naming themes, Phase 6: producing the report". Initially the coding was done manually, tools like NVivo software was used when needed. To guarantee the reliability of the findings, the codes were reviewed by an impartial party (e.g., an independent researcher).

Quantitative data collected from surveys are analysed using Partial Least Squares Structural Equation Modeling (PLS-SEM). Since the study has complex relationships with multiple mediators, PLS-SEM can estimate direct and indirect effects simultaneously. With PLS-SEM the evaluation of the relationships is more appropriate since it allows the assessment even when theoretical foundations are still developing (Hair et al., 2014). The analysis followed two steps according to Basbeth and Ibrahim (2018):

- **First step:** before testing the relationships, the measurement model used should be evaluated for reliability and validity. By making sure that the survey questions are consistent using measure such as Cronbach's alpha and composite reliability. Using HTMT criterion confirming that different concepts are truly different from each other to ensure discriminant validity, and using AVE (Average Variance Extracted) making sure that the items are measuring the same concepts, do so.

- **Second step:** once the measurements used have been deemed useful and good, the actual hypothesis testing begins (the relationships between variables). This is done by examining the path coefficients, Effect Size (f^2), Predictive Relevance (Q^2), and Coefficient of Determination (R^2 value). And bootstrapping by repeatedly testing the data in order to check reliability and significance of the results, from direct and indirect effects.

Through this process, PLS-SEM is ensured to provide rigorous means of testing the study's hypotheses, and answering the research questions. Moreover, offering predictions on how BIM-Lean integration impacts project outcomes in the architectural design process in Palestine.

3.11 Ethical Considerations

Since the study employed a mixed method approach that involves quantitative and qualitative data collection, many ethical considerations were taken into account in order to ensure integrity, reliability, and credibility of the research process and results.

First, all participants were informed about the study's purpose, scope, and methodology prior to data collection, assuring that their participation in the study is utterly voluntary and can withdraw from the study at any stage. Second, anonymity and confidentiality were maintained through the whole process, all participants identities were anonymized. Third, data security was insured by storing all collected data on a password protected device, and restricting access to only the researcher. Finally, academic integrity was upheld throughout the whole research, all of the secondary data and previous works were properly cited and acknowledged according to APA 7 guidelines.

Following these ethical considerations, the study secured the protection of the participants' rights, guaranteed transparency, and ensured the academic integrity of the findings.

3.12 Chapter Summary

This chapter has presented the methodological framework that was adopted to achieve the study's objectives on the BIM-Lean integration in the Palestinian AEC industry. It first started by discussing the pragmatic philosophy that the research was based upon, then it delved into explaining the mixed method approach that was used the process, from qualitative and quantitative methods.

The chapter then goes into describing the research strategy, design, approach, data collection, instruments including pilot testing and questionnaire structure. Population, sampling, and unit of analysis was presented after that. Then it discussed data analysis techniques underscoring the use of Partial Least Squares Structural Equation Modeling (PLS-SEM) for the quantitative and thematic analysis for the qualitative data.

Finally, the chapter ends by addressing the ethical considerations that the study has followed to guarantee confidentiality, informed consent, and academic integrity. In summary, the methodology that is presented in this chapter establishes groundwork for the analysis of the results in the upcoming chapters.

Chapter Four: Results

4.1 Overview

This chapter presents the quantitative and qualitative findings of the study to examine the adoption of BIM-Lean integration in the architectural design process in Palestine. The quantitative data were derived from a structured questionnaire, providing insights about BIM maturity levels, Lean adoption, perceived impacts, and the implementation barriers across the AEC industry in Palestine. Descriptive statistics and Structural Equation Modeling (PLS-SEM) are used to analyse the relationships between suggested constructs and to test the study hypotheses.

In addition to the questionnaire results, this chapter reports qualitative findings that are derived from semi-structured interviews, which focus on the participants' experience with BIM and Lean implementation, Design Coordination, Information Flow Quality, Collaborative Workflow, project outcomes, and the perceived barriers. By presenting both data sources, this chapter provides a comprehensive overview of the current BIM-Lean practices and their effects in the architectural design process in Palestine.

4.2 Respondent Profile

This subsection highlights the profile of the respondents who have participated in the study's questionnaire. It describes the respondents' sociodemographic characteristics, background, and the level of familiarity with BIM and Lean among them. Providing context is essential for the quantitative analysis later in the chapter.

4.2.1 Sociodemographic Characteristics

This section presents the sociodemographic characteristics of the respondents, including their age and location. The data collected from the questionnaire show that the

respondents represent a range of age groups and exhibit diversity in professional experience across the Palestinian AEC industry. In addition, the geographical distribution indicates that people from various cities in Palestine have participated, which ensures the inclusion of diverse regional perspectives.

Figure 4.1 presents the respondents' age distribution. Results demonstrate that nearly half of the respondents (47.9%) fall in the 20-30 age group, being the largest proportion of the sample. Followed by the age group 31-40 (24.5%), respondents aged 41-50 and those aged 50+ account for 11.3% and 16.3% of the sample, respectively. This spread of ages highlights the inclusion of professionals from various age groups within the AEC industry in Palestine.

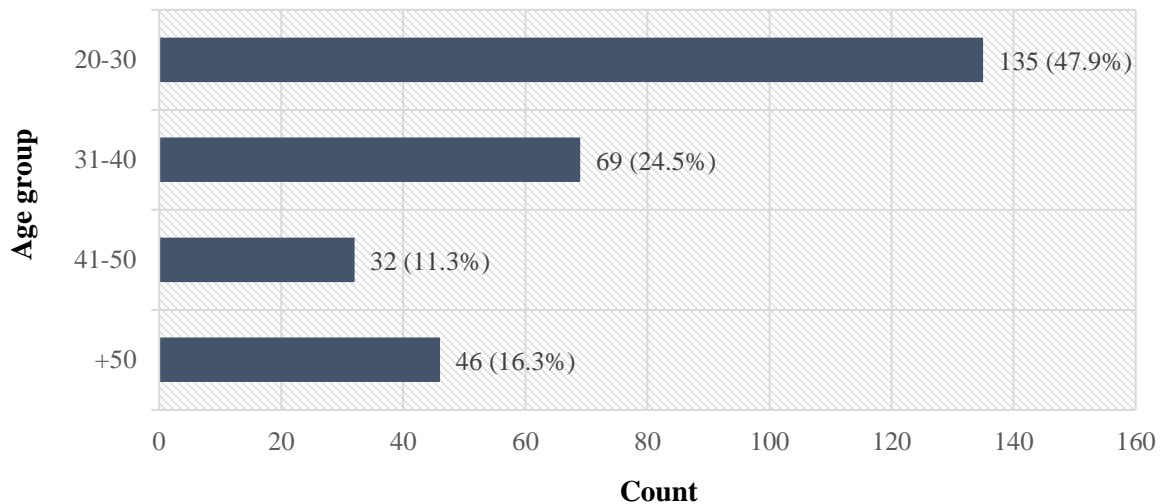


Figure 4.1 Age Distribution Among Respondents

Figure 4.2 presents the geographical distribution of the respondents across major cities in Palestine. The results reveal that most of the respondents are from Ramallah with a 24.82% and Hebron with a 22.7%, followed by Bethlehem (18.44%), Nablus (14.18%), Jenin (8.87%), and Tulkarm (6.74%), these cities represent the main hubs of architectural and construction activity in Palestine, and have the largest concentration of AEC firms. A

small percentage of respondents (4.26%) were located in cities such as Jerusalem and Tubas. Due to their limited representation, and to stay aligned with the study scope, they were grouped under the category “Other cities”. Overall, the distribution reflects representation from the major urban cities in Palestine.

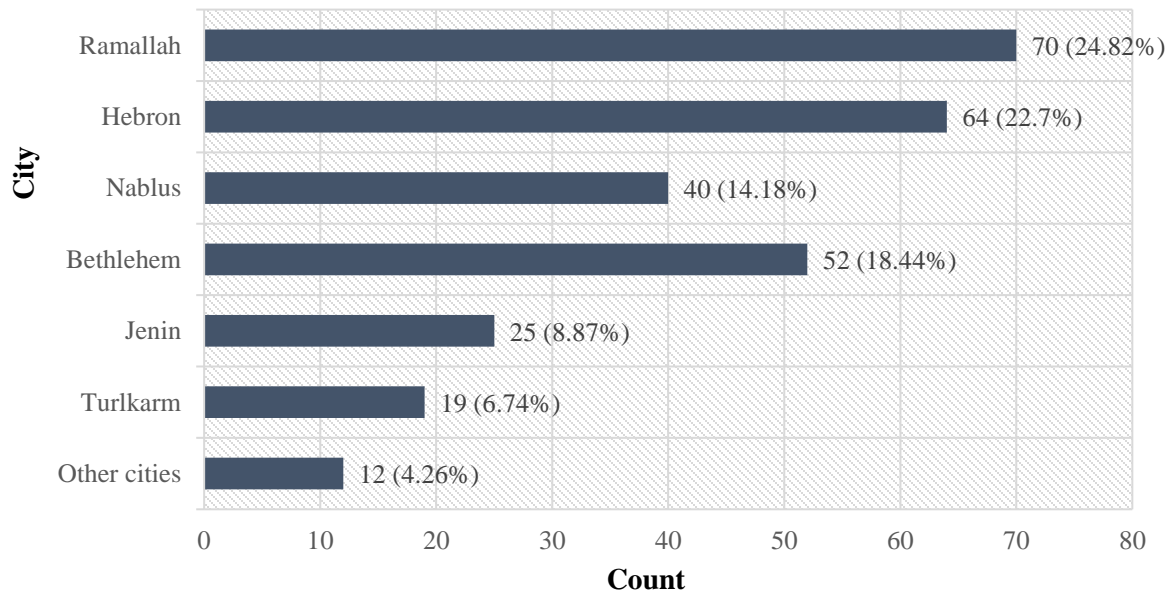


Figure 4.2 Geographical Distribution Among Respondents

4.2.2 Professional Background and Firm Characteristics

This subsection presents the respondents’ professional backgrounds and the characteristics of the firms they represent. Providing an overview of the respondents’ professional roles, years of experience, and the organizational context of their firms.

As shown in Figure 4.3, respondents are distributed across firms from various types within the AEC industry, with the Architectural firms accounting for the largest proportion of the sample of 187 (66.31%). Followed by civil 53 (18.79), then Mechanical 26 (9.22%), then Electrical 12 (4.26%). Lastly, other firm types such as contracting, communication, project management and digital construction, and all discipline design and consulting, each

had one respondent, and, due to their limited representation, they have been grouped as “Other”, totalling 4 at 1.42%.

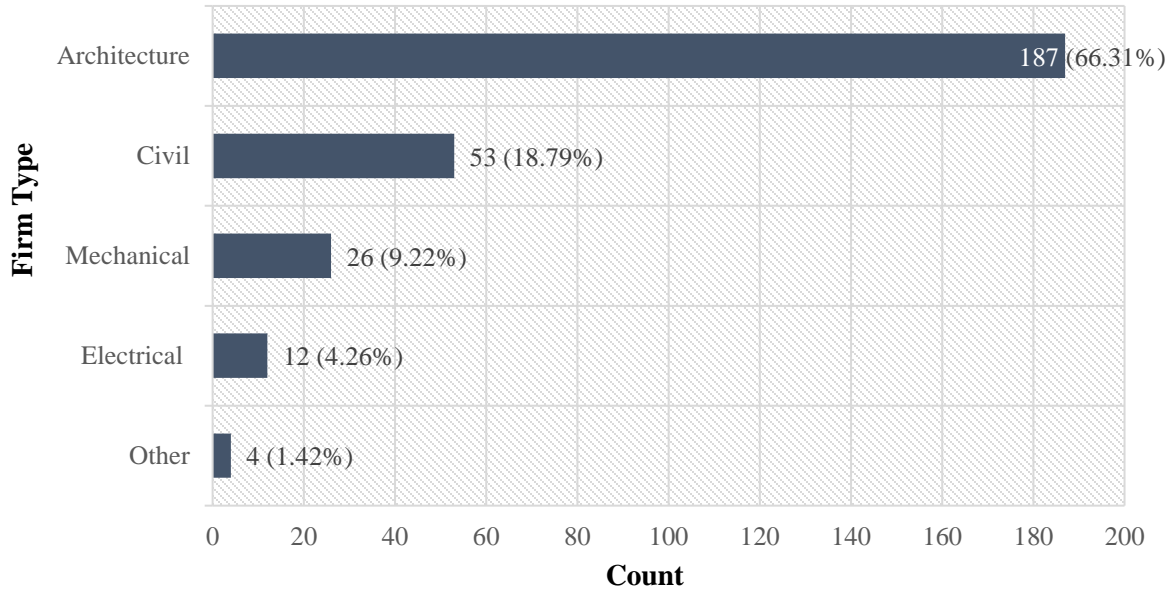


Figure 4.3 Firm Type

Figure 4.4 presents the classification of the firms that have participated in the study. The findings indicate that a substantial proportion of respondents are employed at a consulting firm of type 102, at 36.17%. Followed by the second largest group type, which is contracting 64 (22.69%), the sample also included firm types such as First with 51 (18.09%), Third 45 (15.96%), and Second with 20 (7.09%).

This variation in the classification of firms provides insights into the scale and capacity of the organization, which ensures that the data reflects perspectives from firms with different operational scopes, and different levels of engagement in the market in the AEC industry in Palestine.

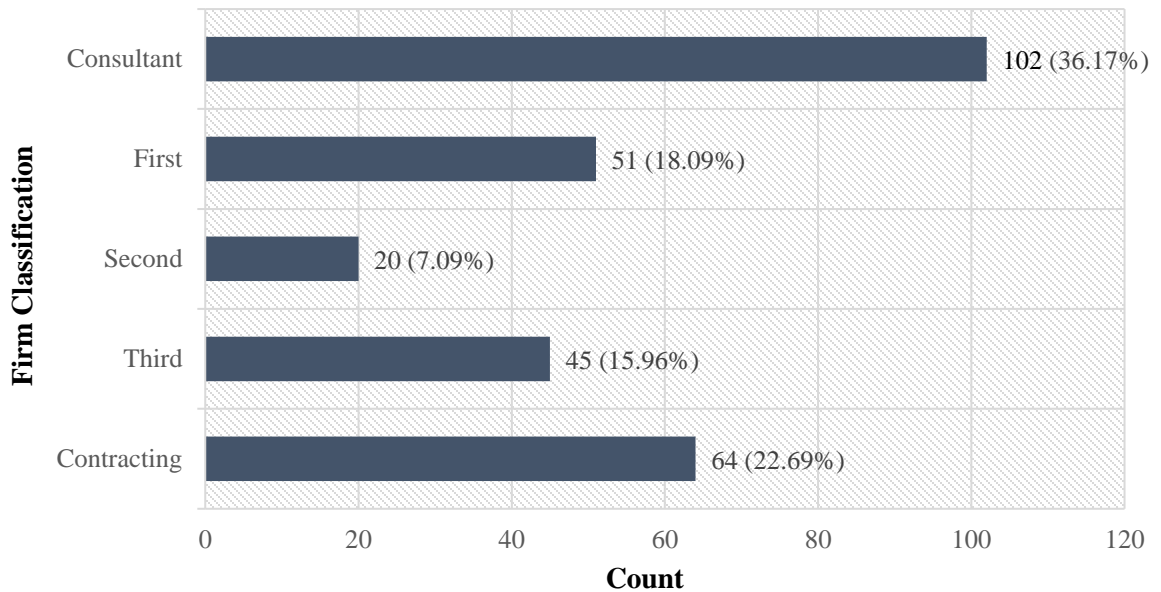


Figure 4.4 Firm Classification

Figure 4.5 illustrates the professional positions that are held by the respondents. The results indicate that architects are the largest group, with 186 responses (66%). Followed by engineers and individuals that are in managerial roles, 72 (25.5%), and 61 (21.6%), respectively. It should be noted that in this question, participants can choose more than one role, as some individuals simultaneously hold, for example, architectural and managerial responsibilities within their organization. This reflects the overlapping roles that are very common in the AEC industry. Hence why the total number of responses exceeds the total numbers of respondents.

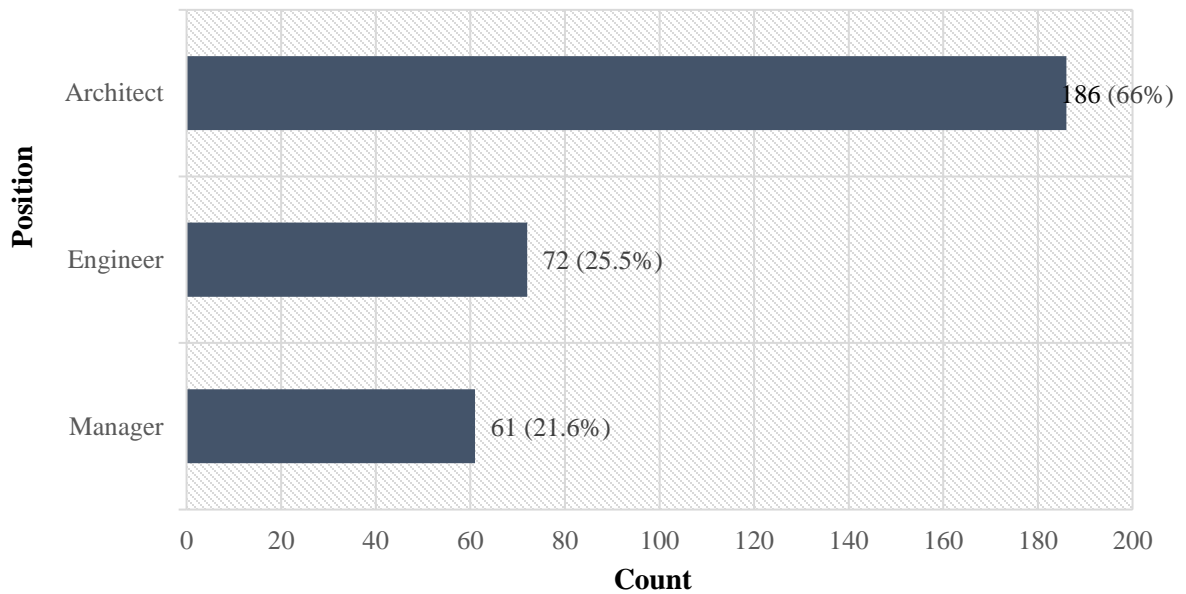


Figure 4.5 Professional Role

Figure 4.6 shows the respondents' years of experience. Almost half of the respondents have between 0 and 5 years of experience, with 134 responses (47.52%), which is expected since the largest age group in the results was 20-30 years. While the remaining respondents are distributed across higher experience ranges, 6-10 years with 64 (22.7%), followed by +20 years of experience with 51 (18.09%), and lastly, the mid-career-to-senior professional range with 11-19 years of experience, 33 (11.7%).

This spread indicates the participation of respondents from both early-career and highly experienced groups. This allows the study to capture a broad range of insights regarding the practices of BIM and Lean.

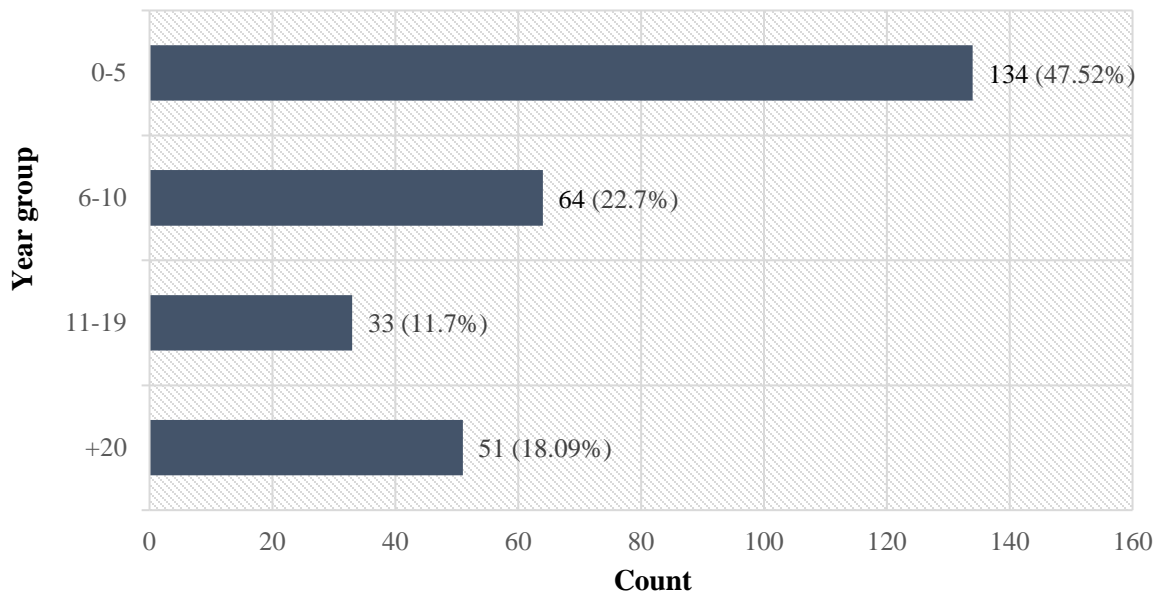


Figure 4.6 Years of Experience

4.2.3 Familiarity with BIM and Lean Practices

This subsection examines the respondents' familiarity with both Building Information Modeling (BIM) and Lean practices to provide context regarding their ability to engage with BIM-Lean integration. Understanding respondents' awareness and exposure to these approaches is important for meaningfully interpreting their perceptions and responses in the qualitative analysis that follows.

Figure 4.7 presents the respondents' self-reported familiarity with BIM. The results indicate that a larger number of the respondents have high to very high familiarity with BIM. While others demonstrate moderate to low levels of familiarity. This distribution indicates different levels of exposure to BIM technologies. The high level of reported familiarity can be explained by the age composition of the sample, as the younger age group 20-30 was the largest reporting 47.9%, which means they are more likely to have been

introduced to BIM tools during their education, where such technologies are integrated in their architectural and engineering curricula.

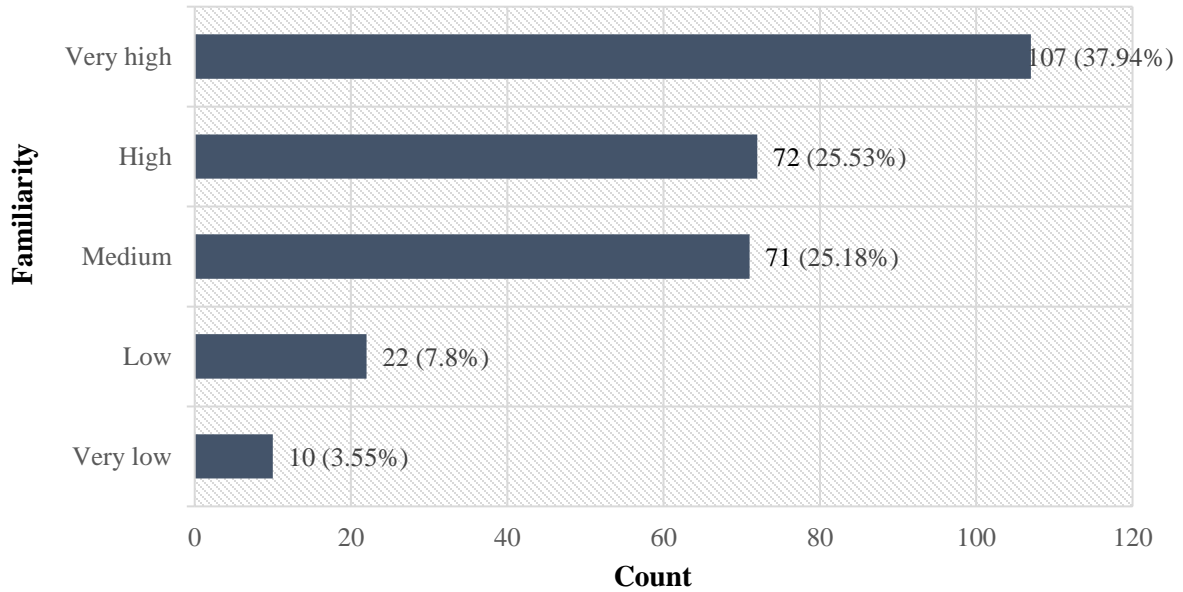


Figure 4.7 Familiarity with BIM

As noticed BIM was referenced alongside Revit in the questionnaire, as many professionals commonly associate their experience with the software itself rather than BIM.

Figure 4.8 presents the respondents' familiarity with Lean practices. The findings show a mixed level of familiarity and engagement. The majority of respondents, 121 (42.9%), reported medium familiarity with Lean practices, suggesting general awareness of Lean concepts among professionals. But when examining the practical use, as shown in Figure 4.9, the majority of respondents indicated that Lean is used occasionally (108 respondents, 38.3%), and 26.6% of them plan to use it in the future. This reflects the nature of Lean implementation in practice, as awareness doesn't necessarily mean regular application within the organization.

The question leading to figure 4.9 allowed multiple responses as some respondents may not currently apply Lean practices but plan to do so in the future.

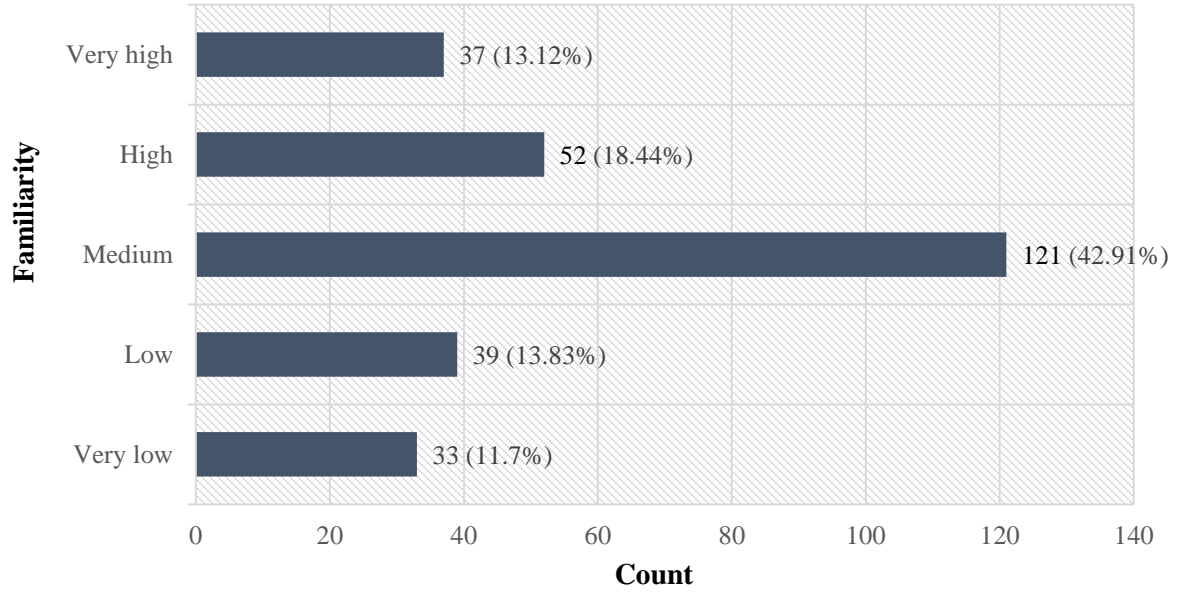


Figure 4.8 Familiarity with Lean

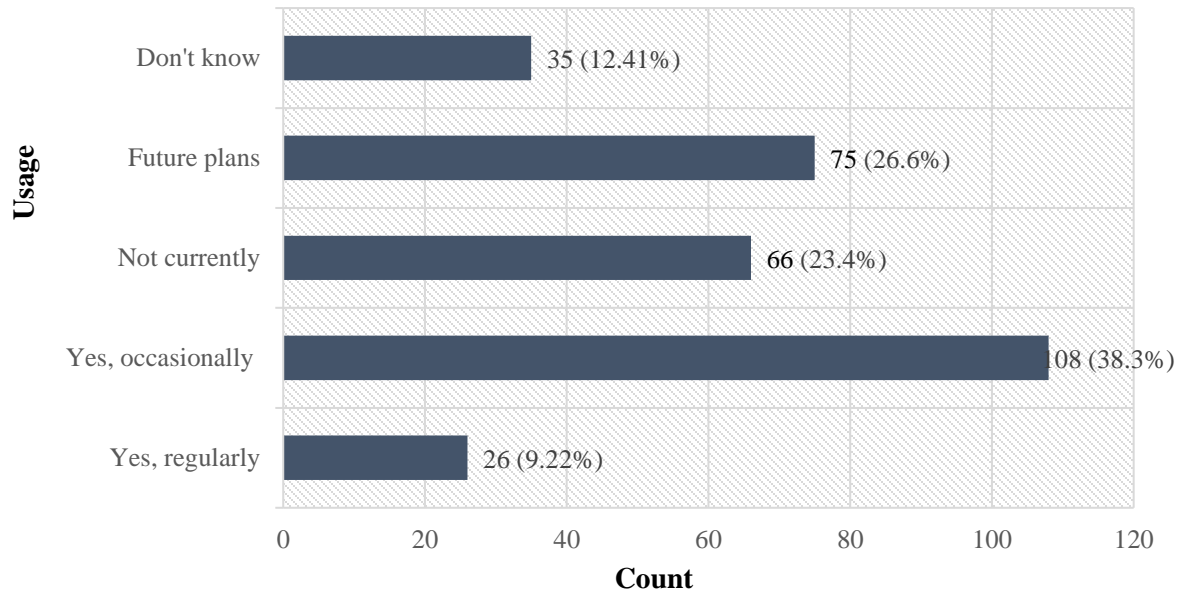


Figure 4.9 Lean practices Usage

4.3 Descriptive Statistics

This section presents the descriptive statistics of the main study constructs. Table 4.1 illustrates the mean values and standard deviations for BIM-Lean integration, Design Coordination, Information Flow Quality, Collaborative Workflow, Efficiency Enhancement, and Collaborative Effectiveness.

The findings indicate that respondents generally held moderate to high perceptions of the adoption of BIM-Lean integration and its related variables in the architectural design process in Palestine. The constructs that scored the highest mean values are Efficiency Enhancement and Collaborative Effectiveness. This suggests that the respondents have experienced notable improvements in efficiency and collaboration. Design Coordination and BIM-Lean integration have also achieved high mean values, reflecting positive perceptions of their practices.

On the other hand, Information Flow Quality had a lower mean and a higher standard deviation, indicating inconsistency in how respondents perceive the effectiveness of information exchange. This suggests that information flow remains a challenging aspect and varies across firms and project settings, despite the growing use of digital technologies.

Overall, the observed standard deviation values showed moderate variability. This highlights the differences in organizational practices, environment, and most importantly, the level to which BIM-Lean principles are applied.

Table 4.1 Descriptive Statistics of Study Constructs

| Construct | Mean | Standard Deviation |
|----------------------------------|-------------|---------------------------|
| BIM-Lean integration (BL) | 3.89 | 1.01 |
| Design Coordination (DC) | 3.94 | 1.01 |

| | | |
|---|------|------|
| Information Flow Quality (IFQ) | 3.69 | 1.10 |
| Collaborative Workflow (CW) | 3.76 | 1.08 |
| Efficiency Enhancement (EE) | 4.02 | 1.08 |
| Collaborative Effectiveness (CE) | 4.01 | 0.98 |

Based on the descriptive analysis of the variables, the following section evaluates the measurement model using Partial Least Squares Equation Modeling (PLS-SEM) in order to assess the reliability and validity of the constructs.

4.4 Measurement Model Assessment (PLS-SEM)

4.4.1 Indicator Reliability

Indicator reliability was assessed by analysing the outer loading values of each measurement item on its associated construct. According to guidelines and as stated by Haji-Othman et al. (2024) when outer loading values are 0.708 or higher suggests that the items sufficiently captured the construct, “if the outer loadings of items in a specific construct are high, then the items have much in common captured by the construct.” (p. 2384).

The results show that the majority of the indicators’ outer loading values are above the recommended 0.708 threshold, which confirms an acceptable level of indicator reliability. Even though a small number of indicators had lower loading than 0.708, the indicators were retained because AVE and composite reliability remained acceptable, and content validity was preserved.

Overall, the results confirm that the measurement indicators provide a reliable representation of their underlying construct.

4.4.2 Internal Consistency Reliability

Internal consistency reliability was evaluated using Cronbach's alpha and composite reliability in SmartPLS. Cronbach's alpha is considered to be more of a traditional measure of reliability, while composite reliability is more appropriate in PLS-SEM as it doesn't assume equal indicator loadings.

The results indicate that the composite reliability values for all constructs exceed the recommended threshold of 0.70, indicating satisfactory internal consistency. Cronbach's alpha also fell within acceptable ranges, especially given the exploratory research approach. Overall, these findings confirm that the measurement model has sufficient internal consistency.

Table 4.2 Reliability and Convergent Validity of the Measurement Model

| Construct | Cronbach's Alpha | Composite Reliability (pc) | AVE |
|------------------|-------------------------|-----------------------------------|------------|
| BL | 0.650 | 0.810 | 0.60 |
| DC | 0.903 | 0.939 | 0.837 |
| IFQ | 0.579 | 0.770 | 0.542 |
| CW | 0.715 | 0.844 | 0.648 |
| EE | 0.726 | 0.845 | 0.647 |
| CE | 0.739 | 0.837 | 0.632 |

(Source: SmartPLS output)

4.4.3 Convergent Validity

The convergent validity was evaluated using the Average Variance Extracted (AVE). The AVE values for the obtained results were greater than 0.50; this means that a construct explains half of the variance of its indicators. The results show that all constructs have AVE

values exceeding the recommended threshold, as shown in Table 4.2, which also reports the AVE values. This confirms that convergent validity is adequately established for the measurement model.

4.4.4 Discriminant Validity

Discriminant validity was evaluated using the heterotrait-monotrait ratio (HTMT) with bias-corrected bootstrapped confidence intervals. It evaluates discriminant validity by examining whether the interval includes 1.0.

The findings show that some constructs have HTMT confidence intervals below the established threshold, indicating discriminant validity. In others, the upper bounds of the confidence intervals slightly exceed 1.0. This represents a limitation of the study, indicating that there might be potential overlap between constructs, hence why related findings should be interpreted with caution, especially for constructs that are theoretically and conceptually aligned within the BIM-Lean integration context.

Considering the interrelated and integrated nature of the study variables, such results are theoretically expected and consistent with prior research on complex organizational and process-driven constructs. Overall, discriminant validity is considered acceptable for the purpose of this study. Detailed HTMT results are available in Appendix D.

4.5 Structural Model Results

4.5.1 Path Coefficients and Hypothesis Testing

The structural model was assessed by examining standardized path coefficients via bootstrapping. Table 4.3 shows the path coefficients, t-values, and p-values for the hypothesized relationships. The results indicate that all proposed paths are statistically

significant at the 0.05 level, providing empirical support for the hypothesized relationships in the structural model.

Table 4.3 Path Coefficients and Hypothesis Testing Results

| Hypothesis | Path | β | t-value | p-value | Decision |
|------------|--------|---------|---------|---------|-----------|
| H1 | BL-DC | 0.789 | 32.901 | < 0.001 | Supported |
| H2 | BL-IFQ | 0.764 | 26.161 | < 0.001 | Supported |
| H3 | BL-CW | 0.655 | 11.38 | < 0.001 | Supported |
| H4 | DC-EE | 0.672 | 13.107 | < 0.001 | Supported |
| H5 | IFQ-EE | 0.227 | 4.094 | < 0.001 | Supported |
| H6 | CW-CE | 0.659 | 19.065 | < 0.001 | Supported |

(Source: SmartPLS, PLS-SEM algorithm results)

4.5.2 Coefficient of Determination (R^2)

The coefficient of determination (R^2) was used to evaluate the explanatory power of the structural model. The obtained results demonstrate how the structural model explains a substantial proportion of the variance in Efficiency Enhancement, with an R^2 of 0.74. While the moderate levels of explained variance were observed for Design Coordination, Information Flow Quality, Collaborative Workflow, and Collaborative Effectiveness. Overall, the R^2 values indicate that the model explains a reasonable amount of variance.

Table 4.4 Coefficient of Determination (R^2) of Dependent Constructs

| Construct | R^2 | Interpretation |
|-----------|-------|----------------|
| DC | 0.623 | Moderate |
| IFQ | 0.584 | Moderate |
| CW | 0.428 | Moderate |

| | | |
|-----------|-------|-------------|
| EE | 0.740 | Substantial |
| CE | 0.434 | Moderate |

(Source: SmartPLS, PLS-SEM algorithm results)

4.5.3 Effect Size (f²)

The effect size (f²) was used to assess the magnitude of the independent variables' impact on the dependent variables. The findings illustrate how BIM-Lean integration has a very large effect on Design Coordination, Information Flow Quality, and Collaborative Workflow. The results also demonstrate how Design Coordination has a substantial effect on Efficiency Enhancement. Whereas Information Flow Quality had a small effect on Efficiency Enhancement compared to the other variables. Overall, the f² values highlight the significance of the relationships specified in the structural model.

Table 4.5 Effect Size (f²) Values of the Structural Model Relationships

| Path | f² | Effect Size |
|---------------|----------------------|--------------------|
| BL-DC | 1.651 | Large |
| BL-IFQ | 1.401 | Large |
| BL-CW | 0.749 | Large |
| DC-EE | 0.683 | Large |
| IFQ-EE | 0.078 | Small |
| CW-CE | 0.768 | Large |

(Source: SmartPLS, PLS-SEM results)

4.5.4 Mediation Analysis

Mediation analysis was conducted using bootstrapping in SmartPLS to investigate the indirect effects of BIM-Lean integration on Efficiency Enhancement and Collaborative

Effectiveness through the proposed mediators. Results show that the proposed mediators are statistically significant, illustrating how BIM-Lean integration has an indirect effect on Efficiency Enhancement through Design Coordination and Information Flow Quality. This confirms the presence of the suggested mediators in the structural model.

Table 4.6 Specific Indirect Effects (Mediation Analysis)

| Indirect Path | B (Indirect Effect) | t-value | p-value | Mediation |
|----------------------|----------------------------|----------------|----------------|------------------|
| BL-DC-EE | 0.530 | 11.36 | < 0.001 | Supported |
| BL-IFQ-EE | 0.173 | 3.92 | < 0.001 | Supported |
| BL-CW-CE | 0.431 | 8.23 | < 0.001 | Supported |

(Source: SmartPLS, Bootstrapping results)

4.6 Qualitative Findings

4.6.1 BIM-Lean Integration in the architectural Design Process in Palestine

The qualitative findings suggest that the integration of Building Information Modeling (BIM) and Lean practices in the Palestinian architectural design process is still evolving and has not yet reached full maturity, as it's still in its early stages. Although interviewees were generally familiar with BIM tools and had a basic awareness of Lean concepts, the depth and consistency of their approaches differed significantly across organizations and project settings.

The majority of architects demonstrated that BIM is used more as a tool for design development and documentation, 3D modelling, and visualization. In some cases, BIM was used for clash detection with limited interdisciplinary coordination, especially with civil and mechanical engineers. Nevertheless, only a limited number of interviewees have described BIM as a fully integrated platform with real-time model sharing and coordination amongst

disciplines. These findings highlight an industry pattern where BIM is implemented at a technical level rather than a holistic process-driven methodology.

As for Lean practices, findings demonstrated that they were rarely implemented through standardized procedures. Most of the participants described that Lean was more implemented in an informal and implicit manner, primarily through initiatives that aim to reduce rework and enhance internal coordination and/or efficiency. Several interviewees noted that these practices were not labelled as “Lean” within their organization, as they were more of a routine process or practices that came from professional experience. This indicated how, even though Lean practices are evident in projects, processes, and operations, they still remain unstructured and lack formal institutional support.

As a result, the BIM-Lean integration was considered inconsistent and fragmented, as its effectiveness is shaped by the individual expertise, project complexity, and the extent to which the stakeholders are willing to engage in digital collaboration. Architects with longer professional experience have reported a stronger alignment between BIM capabilities and Lean objectives, particularly in problem detection, improving design predictability, and reducing waste during the design phase. In contrast, participants in smaller firms or working on project with minimal BIM requirements have reported weaker integration outcomes; this is often due to tighter schedules, limited training, and traditional project delivery expectations.

In substance, many interviewees have highlighted a disconnect between academic exposure and professional practice, explaining that while BIM and Lean concepts are widely introduced at the university level, their implementation in real-world projects is very limited, mainly due to client demands, financial constraints, and the absence of clear standards. This

affects the practical application of BIM-Lean integration and leads to continued dependence on traditional approaches.

Overall, the results of the qualitative analysis on the integration of BIM-Lean indicate that BIM-Lean integration is recognized but remains highly fragmented at the operational level. Even though BIM provides a technological foundation that supports Lean objectives, the full realization of the benefits of BIM-lean integration is hindered by the lack of formal Lean adoption and low BIM maturity across many firms. These qualitative insights reinforce the view that successful BIM-Lean integration requires more than technological adoption; it also requires a supportive culture, training, and organizational readiness within the architectural practice.

4.6.2 Design Coordination, Information Flow Quality, and Collaborative Workflow

The qualitative findings have indicated that the BIM-Lean integration has a clear but uneven impact on Design Coordination, Information Flow Quality, and Collaborative Workflow in the architectural design process in Palestine. The interviewees have explained how these three variables are interconnected and how difficult they are to treat separately in practice. They added that, for example, improvements in Design Coordination are driven by the quality of information and the level of interdisciplinary collaboration enabled by BIM tools.

The majority of architects have highlighted that BIM has improved Design Coordination, particularly in collaboration with structural and MEP engineers. The shared BIM model has aided in identifying problems in the early stages of the design, which has helped with decision making, reducing rework, and late changes. Moreover, they have noted that coordination has been more efficient with BIM because the shared model serves as a

reference, allowing problems to be discussed visually rather than through separate 2D drawings. However, the level of improvement heavily depends on the BIM skills and the commitment of all the involved parties. In cases where external consultants did not fully use BIM, coordination outcomes were limited and inconsistent.

As for Information Flow Quality, interviewees have highlighted how BIM generally improved the accuracy, clarity, and traceability of design information. Underscoring how information exchange became more organized, it reduced misunderstandings that are caused by inconsistent drawings or undocumented changes. Still, some challenges remain regarding Information Flow Quality, especially in projects with tight schedules and unclear responsibilities. Many of the interviewed architects explained that BIM does help the improvement of information management, but its effectiveness is not as prominent when it's not aligned with Lean principles.

In terms of Collaborative Workflow, results show that firms that use BIM tend to adopt a more collaborative and transparent workflow. Architects who have recorded a higher BIM maturity level reported better cross-disciplinary collaboration through shared models and ongoing communication, which supports Lean goals such as reducing waste and improving efficiency. On the other hand, firms with lower BIM maturity levels or limited Lean awareness operate in a more hierarchical, discipline-based manner, using BIM as a digital, individual tool rather than a collaborative platform.

Interviewees' responses highlighted the important role of the organizational and cultural conditions in shaping coordination and collaboration outcomes. Some of the major challenges and barriers to implementing BIM-Lean integration that were frequently mentioned include time pressure, resistance to change, and insufficient training. These

challenges have led to a fragmented adoption of BIM and Lean, where BIM is more used as a tool for drawings rather than being fully aligned with Lean practices and workflows.

Overall, the qualitative findings indicate that BIM-Lean integration can improve Design Coordination, Information Flow Quality, and Collaborative Workflow in the architectural design process in Palestine. However, especially in Palestine, these benefits are unevenly applied and heavily depend on the organizational readiness, commitment, and BIM maturity. Results demonstrate that technology alone is not enough; effective integration requires more than that, including standardized processes and a supportive organizational culture.

4.6.3 Project Outcomes Reported by Interviewees

Interviewees generally reported positive project outcomes from the use of BIM and Lean practices during the architectural design phase. However, the benefits varied with the level of BIM and Lean usage and the degree to which they were applied in practice. Many participants emphasized that BIM supports earlier identification of design inconsistencies across disciplines, which results in reduced rework and little to no late-stage design modifications.

Several interviewees reported improvements in workflow efficiency and decision-making during the architectural design process, highlighting that the shared digital models via BIM have improved communication and resolved design issues faster and more accurately. But, these benefits were mainly observed in projects that have a higher BIM levels of maturity, and a higher awareness level of Lean, as when BIM was only used for visualization, its impact on efficiency and waste reduction was reported to be limited.

Overall, the interview results indicate that BIM and Lean practices are generally viewed as positively impacting project outcomes during the architectural design process, although these impacts vary by project. These differences in the reported outcomes reflect varying levels of BIM maturity, project-specific demands, and diverse organizational approaches among firms participating in the study.

4.6.4 Barriers and Future Outlook for BIM-Lean integration in Palestine

Interviewees have identified several ongoing barriers to the effective integration of BIM and Lean practices in the architectural process in Palestine. These barriers were consistently reported by participants regardless of their years of experience or firm size.

A commonly repeated barrier was the lack of training and practical expertise in both BIM and Lean practices. While basic BIM use is common, participants emphasized that advanced collaborative capabilities and formal Lean applications are still lacking. Resistance to change, especially among senior staff, external consultant, and those who are used traditional design workflows, further constrain BIM-Lean implementation despite the availability of digital tools.

Participants have also pointed time pressure as a key barrier, noting that deadlines reduce the ability to apply Lean practices or conduct continuous coordination. In these situations, BIM tends to be used more as a tool to complete required deliverables. Limited client demand and financial constraints are among the prominent and frequent challenges mentioned; these obstacles have contributed to reduced motivation to invest in training, standardize workflows, and implement advanced BIM-Lean integration, especially in small projects where such integration is not perceived as essential.

Interviewees were optimistic about the future of BIM-Lean integration in Palestine, stating that gradual growth is possible if supported by younger professionals and increasing digital awareness. However, many have expressed that a broader BIM-Lean adoption depends on enhanced training programs, clear guidelines, and stronger institutional support. Overall, findings suggest that while BIM-Lean integration is well recognized, its development depends on resolving the current practical and organizational barriers.

4.7 Chapter Summary

This chapter presented the study's empirical results by integrating quantitative and qualitative findings to examine the adoption of BIM and Lean practices in the Palestinian architectural design process. The quantitative results showed varying BIM maturity levels and a fragmented implementation of BIM and Lean, shaped by organizational and skill-related limitations, while the PLS-SEM analysis confirmed significant relationships among the study constructs.

The qualitative findings have supported the quantitative results, highlighting the largely informal application of Lean practices and BIM use, along with several barriers and challenges, including a lack of training, resistance to change, time pressure, limited client demands, and financial constraints. Overall, the results presented in this chapter have provided an understanding about the current state of BIM-Lean integration in the Palestinian architectural design process. Moreover, it provided an empirical basis for the discussion that is presented in the following chapter.

Chapter Five: Discussion and Conclusions

5.1 Overview

This chapter presents a comprehensive discussion of the study findings and their implications for BIM-Lean integration in the Palestinian architectural design process. The chapter discusses the quantitative and qualitative findings in relation to the research questions, objectives, and hypotheses.

The chapter starts by discussing BIM-Lean integration in the architectural design process, followed by an analytical discussion of the study's key variable impact on project outcomes. Then it examines the mediating effects of Design Coordination, Information Flow Quality, and Collaborative Workflow on Efficiency Enhancement and Collaborative Effectiveness. The chapter also addresses the barriers and challenges that affect BIM-Lean integration. Finally, practical strategies for enhancing efficiency and reducing waste in Palestine are proposed, and the chapter concludes the study by summarizing the overall key insights of the research.

5.2 BIM-Lean Integration in the Architectural Design Process

This section discusses how BIM-Lean integration affects key architectural design process constructs in Palestine. These constructs/variables, Design Coordination, Information Flow Quality, and Collaborative Workflow, are the primary dimensions in which BIM-Lean integration impacts project outcomes, as proposed in the study's hypotheses H1, H2, and H3. The discussion is based on the quantitative results from the PLS-SEM analysis and is supported by the qualitative findings presented in Chapter 4.

Overall, the results indicate that BIM-Lean integration has a strong and statistically significant effect on the three constructs. However, the observed variations in the strength

and consistency of the proposed relationships suggest that the outcomes of BIM-Lean integration depend on more than technical adoption alone. The organization's readiness, management support, and industry constraints in the AEC industry in Palestine also play a decisive role in determining the extent of BIM-Lean integration's effectiveness in improving the architectural design process.

5.2.1 Design Coordination (H1)

The results indicate that BIM-Lean integration has the most substantial impact on Design Coordination among the examined constructs, providing strong empirical support for the proposed hypothesis H1. This relationship indicates that BIM-Lean integration is very effective in providing coordination between different disciplines, including architects, engineers (structural and MEP), and managers, in the architectural design process.

In practice, BIM enables different teams to work together through its shared platform and digital model. Lean focuses on work coordination, which, when done early, helps avoid later problems. When these two are used together, they identify conflicts early and reduce changes made late in the design phase. Qualitative findings from interviews reinforce this, as they explain that BIM-Lean integration made designs clearer, enabled visual problem-solving, and reduced misunderstandings across disciplines.

Even though results show a strong relationship between BIM-Lean integration and Design Coordination, qualitative findings indicate that improvements in coordination are rather conditional than automatic. Interviewees reported that coordination improved most when all disciplines actively used BIM models and when coordination activities were well organized. But when BIM was applied informally, the improvements in coordination were

less reliable. This demonstrates that while BIM-Lean integration strongly enhances Design Coordination, its impact depends on teamwork and structured workflows.

5.2.2 Information Flow Quality (H2)

Results indicated a positive relationship between BIM-Lean integration and Information Flow Quality, supporting the proposed hypothesis H2. However, compared to Design Coordination, Information Flow Quality appears to be a challenging and less consistent construct in the architectural design process. This suggests that improving information flow within the design process is more complex and sensitive to contextual conditions.

Quantitative results showed that IFQ had a lower mean and a higher standard deviation than the other constructs, indicating greater variability in respondents' perceptions. While BIM-Lean integration provides the technical ability to improve information sharing, its effectiveness in practice depends on the project- and firm-specific conditions. Such variations reflect differences in organizational practices, levels of BIM and/or Lean adoption, and the degree to which information management processes are clearly defined. Without clear responsibilities for information exchange, information availability does not translate into improved design performance.

BIM contributes to improving IFQ by centralizing design data in one place, reducing inconsistencies between drawings, and facilitating easier information updates and access. This is supported by Lean, which encourages clear, timely communication, reduces wasted effort related to information management, and enhances the quality of information exchange.

However, the qualitative findings and variations observed in the quantitative results indicate that these improvements are not always realized in practice. Interviewees explained that tight project schedules, varying BIM maturity levels, and the lack of standards for information sharing reduce the effectiveness of BIM-Lean integration, leading to continued reliance on informal communication methods in some projects.

Results indicate that Information Flow Quality has a positive but weak effect on Efficiency Enhancement, suggesting that improving IFQ alone is not sufficient to achieve meaningful efficiency gains unless supported by effective coordination across disciplines. Results highlight the independent nature of BIM-Lean integration, whereas IFQ needs to be embedded in coordination and workflow strategies to achieve meaningful outcomes.

Overall, results reveal that IFQ is an important but sensitive variable. The benefits of this construct depend on organizational commitment level, standardized processes, and higher BIM maturity levels to achieve consistent efficiency enhancements.

5.2.3 Collaborative Workflow (H3)

Results indicate that BIM-Lean integration has a substantial impact on Collaborative Workflow, providing empirical support for the proposed hypothesis H3. This indicates that BIM-Lean integration positively affects how participants interact, coordinate tasks, and collaborate during the architectural design process.

Quantitative results reveal that BIM-Lean integration explains a moderate proportion of variance in Collaborative Workflow, but not all of it. Indicating that while BIM-Lean integration improves collaboration, it's not the only factor. Collaboration in architectural design depends on both digital tools and organizational behaviour, as reported by

interviewees. While BIM provides a real-time shared digital platform, Lean supports collaboration by encouraging teamwork, shared responsibility, and continuous improvement.

Qualitative findings indicate that Collaborative Workflow performs better in organizations with higher BIM maturity and supportive management. Confirming that shared models and coordinated design platforms improved communication, and reduced fragmentation and separation between disciplines when BIM-Lean was used for collaboration.

However, in firms with rigid management or little experience with digital collaboration, BIM was mainly used individually as a drawing and modeling tool. This limited the level of collaboration promoted by Lean practices, demonstrating how the organizational culture, leadership support, and team dynamics are as important as BIM-Lean integration in shaping Collaborative Workflow.

Overall, results indicate that BIM-Lean integration improves Collaborative Workflow in architectural design, but its effectiveness depends on organizational practices and commitment to collaboration. Suggesting that technology alone is not enough for effective collaboration; it requires organizational culture and management support.

5.3 Impact of Design Coordination, Information Flow Quality, and Collaborative Workflow on Project Outcomes

This section discusses the impact of Design Coordination, Information Flow Quality, and Collaborative Workflow on project outcomes in the architectural design process, supporting hypotheses H4, H5, and H6. Results indicate that each of these constructs impacts project outcomes in different ways and at different levels.

5.3.1 Design Coordination Impact on Efficiency Enhancement (H4)

Results show that DC has a strong, positive impact on EE, supporting hypothesis H4. Indicating that better coordination between disciplines during the design phase results in better efficiency. When DC is improved, conflicts and rework in designs are reduced, and technical problems are solved earlier.

BIM-Lean integration enables this by detecting clashes early and facilitating coordinated work and better alignment. Interviewees have reinforced these findings, explaining that BIM-based workflows have helped reduce design changes and enhance efficiency. The results confirm that Design Coordination is a key factor in Efficiency Enhancement in the architectural design process in Palestine.

5.3.2 Information Flow Quality Impact on Efficiency Enhancement (H5)

Results show that IFQ has a positive impact on EE, supporting hypothesis H5. But its effect is weak, indicating that large amounts of data, accurate and timely information, are not enough to achieve Efficiency Enhancement. A better flow of information can reduce delays and rework, but still has a weak impact if it's not met with well-coordinated processes

Qualitative findings support this, as interviewees explained that even though BIM improves the access and handling of information, when the information is not actively used to support coordination decisions, some inefficiencies persist. Overall, Information Flow Quality was proven to play a role in Efficiency Enhancement, but it is not a primary determinant.

5.3.3 Collaborative Workflow Impact on Collaborative Effectiveness (H6)

Results show that CW has a strong and positive impact on CE, supporting hypothesis H6. This confirms that when teams work in a more collaborative manner, the cooperation

between different disciplines improves, as Collaborative Workflow improves communication and joint problem-solving.

BIM-Lean integration enables this by allowing the team to work in synergy on a shared digital platform, making coordination easier. Interviewees have reported that stronger interdisciplinary interactions and better teamwork are notable with a well-developed Collaborative Workflow. Unlike Efficiency Enhancement, Collaborative Effectiveness depends more on teamwork and how well the team members interact and work together.

5.4 Mediating Effects of Design Coordination, Information Flow Quality, and Collaborative Workflow

This section discusses the mediating role of DC, IFQ, and CW in the relationship between BIM-Lean integration and project outcomes, in correspondence with H7. Results from the mediation analysis indicated that BIM-Lean integration impacts Efficiency enhancement and Collaborative Effectiveness in both directions: directly and indirectly through these constructs.

The quantitative results have demonstrated that Design Coordination is the strongest mediator between BIM-Lean integration and Efficiency Enhancement. Indicating that better coordination between teams leads to Efficiency Enhancement, BIM-Lean integration supports this by enabling a well-coordinated shared digital platform that reduces conflicts and rework. The findings highlight Design Coordination as the main construct in which BIM-Lean integration leads to better project outcomes and overall performance.

While Information Flow Quality helps improve efficiency, it has a weaker effect than Design Coordination on Efficiency Enhancement. As explained previously, information sharing alone is not enough unless supported by well-organized coordination between teams.

This means that Information Flow Quality plays a more supporting role. On the other hand, Collaborative Workflow mediates the relationship between BIM-Lean integration and Collaborative Effectiveness. As BIM-Lean enhances collaboration through teamwork, interaction, and shared understanding rather than relying only on technology.

Overall, results demonstrate how BIM-Lean integration improves project outcomes in different ways. Design Coordination is the key variable in which efficiency improves, while Information Flow Quality plays a supporting role and confirms that Collaborative Effectiveness improves through Collaborative Workflow. These results support the proposed structural model, indicating that improving its variables is essential to fully benefit from BIM-Lean integration.

5.5 Barriers and Contextual Factors Affecting BIM-Lean Integration in Palestine

This section discusses the key barriers and challenges affecting the adoption and implementation of BIM and Lean practices in the architectural design process in Palestine, based on both quantitative results and qualitative findings. While the statistical analysis confirms the positive impact of BIM-Lean integration on DC, IFQ, and CW, it also reveals that the organizational and structural challenges limit the consistent application of these approaches across firms.

Questionnaire results indicate that training and skill-related barriers are among the critical challenges to BIM's adoption and effective use. A large proportion of respondents identified skill gaps (89.3%) and a lack of training (76.8%) as major challenges, suggesting that BIM is often introduced without sufficient training and preparation. Qualitative findings support this as interviewees frequently highlighted limited awareness, lack of professional

training, and weak understanding of BIM-Lean beyond technical and basic software use as limiting obstacles.

Resistance to change, reported by 71% of respondents, and organizational culture, have also been identified as obstacles. In addition, the lack of standardized workflows 56.4% was identified as a significant barrier. Similar to BIM, Lean adoption was also constrained by limited awareness (86.4%) and resistance to change (64.9%). This highlights the importance of organizational cultural readiness and alignment, with management support and time-related issues further affecting its implementation.

The findings identified several challenges in the Palestinian AEC industry, including limited client demand for BIM-Lean practices, a lack of standards, and the absence of regulations to support its adoption. Both quantitative and qualitative results showed that BIM and Lean practices are more commonly introduced in academic training or graduation projects, but their application in practice is inconsistent due to financial constraints and traditional project requirements.

Overall, barriers to BIM-Lean integration are more organizational and skill-based than technological in the AEC industry in Palestine. Providing training, improving awareness, and management support is important to move beyond partial adoption and more towards effective implementation. Addressing these challenges enables BIM-Lean integration to enhance efficiency in the architectural design process.

5.6 Findings in Relation to Previous Studies

The findings of this study are consistent with previous research, which highlights the positive role of BIM-Lean integration in improving efficiency and effectiveness through suggested mediators in the architectural design process. Previous research explained how

BIM detects and resolves conflicts early, improve coordination, and aids different disciplines to work together as a team (Abdalhameed & Naimi, 2023; Sacks et al., 2010).

The positive relationship observed between BIM-Lean integration and Design Coordination in this study supports earlier research, confirming that integrating digital tools with process-focused practices is highly effective in the architectural design process.

The study also provides new knowledge in the context of Palestine, adding to the existing literature by offering insights into BIM-Lean integration in a developing country, where most previous studies focused on developed economies. Previous research has shown that information flow is a critical factor in enhancing efficiency (Giarette et al., 2017), but this study's findings indicate that its effect on efficiency is weaker in Palestine, highlighting the importance of organizational readiness and support.

The study identified barriers and challenges related to skills, training, and resistance to change, which align with previous studies conducted in developing countries (Adetoro et al., 2025; Enshassi & AbuHamra, 2017), underscoring the significant impact of organizational and contextual factors on effective BIM-Lean integration.

Overall, the study's findings confirm previous research on BIM-Lean integration and its positive impact on coordination and efficiency in the architectural design process. The research adds to existing knowledge by showing that in developing-country contexts such as Palestine, Design Coordination plays a more decisive role than Information Flow Quality in Efficiency Enhancement.

In addition, results contextualize BIM-Lean integration by highlighting that organizational readiness and management support are critical to its effectiveness,

demonstrating that technology adoption alone is insufficient in resource-limited, fragmented environments.

5.7 Proposed Strategies for Enhancing Efficiency and Effectiveness

Based on the empirical findings of this study, this section offers practical strategies that aim to enhance efficiency and reduce waste in the architectural design process in Palestine. These strategies are based on tested hypotheses, model relationships, mediation analyses, and the identified challenges from the quantitative and qualitative results.

Strategy 1: Improving Design Coordination as the critical factor of efficiency enhancement

With Design Coordination being identified as the strongest contributor to Efficiency Enhancement and a substantial mediator between BIM-Lean integration and project outcomes, firms should be using BIM as a coordination-focused tool rather than limiting its application to drawing production. This requires all disciplines to be brought together in the early stages of the design process to enable integrated model development from the initial stages. Additionally, regular meetings supported by shared BIM models can further enhance interdisciplinary understanding.

When BIM is applied proactively, it reduces rework, detects clashes, and facilitates problem-solving in the early design phase. As a result, it reduces waste, wasted effort, materials, time, and unnecessary revisions, and moves the design process as a whole toward a smoother, more efficient process.

Strategy 2: Building Organizational and Cultural Readiness for BIM-Lean Integration

The findings highlight resistance to change, limited awareness, and limited management support as key barriers significantly impacting BIM-Lean integration

implementation. This indicates that BIM-Lean cannot be effective without the proper culture and work environment. Accordingly, firms should focus on the readiness of their organizations, technological adoption, and management that supports BIM-Lean integration to gain its benefits.

Creating a culture that realizes the critical value of BIM-Lean integration from collaboration, waste reduction, and training leads to long-term success. When the stakeholders of any project understand BIM-Lean's significance, it becomes part of their work environment, rather than a fragmented process, leading to improved efficiency and overall project outcomes.

Strategy 3: Enhancing Efficiency by Integrating Information Flow into Coordinated Design Processes

Results indicated that Information Flow Quality had a positive impact on efficiency, but its' effect is far weaker than Design Coordination. IFQ's impact is limited, especially when information is poorly coordinated, underscoring that accessing large amounts of data doesn't necessarily guarantee better performance or efficiency. Information becomes useful when shared through clear and structured processes.

Therefore, firms should not only focus on the availability of information but also ensure it is clear, relevant, and easy to understand across different disciplines. This can be achieved when firms have standards and rules for information sharing, clear role definitions of data responsibility, and the use of digital tools (e.g., BIM) that support information exchange. This approach prevents confusion and misunderstandings when it comes to handling information, leading to an efficient architectural design process.

Strategy 4: Enhancing Collaborative Effectiveness through structured BIM-Lean Workflows

The findings confirm that Collaborative Effectiveness depends on a well-organized Collaborative Workflow. Therefore, firms should establish clear, structured mechanisms for coordination and cooperation between teams rather than relying on occasional communication to avoid misunderstandings and rework. To improve coordination, firms should define roles and responsibilities to ensure team members understand their contributions and decision-making authority, promote regular, shared problem-solving sessions, and encourage early involvement of different disciplines in the process.

The BIM platform should function as a shared place rather than a separate tool used by individual designers. When teams work together in a shared environment, they develop a deeper understanding of the project, making coordination and decision-making more effective and easier, improving the overall efficiency across the organization.

Strategy 5: Addressing Skill Gaps through Targeted BIM-Lean Training

Skill gaps and a lack of training were identified as prominent barriers to implementing BIM-Lean integration. To overcome these obstacles, firms need to invest in training programs that have both technical BIM skills and Lean thinking. Training should extend beyond the use of BIM to emphasize how BIM improves coordination, supports transparent and smooth information flow, and enables collaborative workflows in the design process.

Firms can move beyond the basic, fragmented use of BIM and Lean when employees develop a clear understanding of BIM-Lean integration and its practical application, leading

to greater efficiency, collaboration, and overall performance in the architectural design process.

5.8 Recommendations for Future Research

This study opens several avenues for future research on BIM-Lean integration in architectural design. Future studies can expand their research beyond the design phase to include construction and other operational stages, extending the scope of this study, which helps provide a more comprehensive view of the impact of BIM-Lean on project outcomes across its lifecycle.

In addition, future studies could explore BIM-Lean integration in other regions of Palestine or in similar developing countries to improve the generalizability of the findings. Future research can also focus on investigating human factors, such as leadership, or organizational factors, such as training approaches and digital maturity, that affect the successful implementation of BIM-Lean integration. Finally, qualitative research can focus on case studies that offer practical recommendations and best practices of BIM-Lean integration.

5.9 Conclusions

This study investigated the integration of Building Information Modeling (BIM) and Lean principles into the architectural design process in Palestine, aiming to identify strategies to enhance efficiency and reduce waste. By adopting a mixed-method approach, the study examined how BIM-Lean integration impacts Design Coordination, Information Flow Quality, Collaborative Workflow, Efficiency Enhancement, and Collaborative Effectiveness.

The empirical findings confirm the positive impact BIM-Lean integration has on the architectural design process. Among the examined constructs, Design Coordination had the most substantial impact on Efficiency Enhancement. Information Flow Quality, on the other hand, played more of a supporting role, and Collaborative Workflow had a positive impact on Collaborative Effectiveness. The study's mediation analysis revealed that BIM-Lean integration indirectly affects Efficiency enhancement and Collaborative Effectiveness through the proposed mediators. This indicates that BIM-Lean integration affects project outcomes through multiple dimensions, both directly and indirectly.

This study advances the BIM-Lean literature by empirically validating the mediating role of intermediate design-process constructs in the architectural context. Previous research has focused on the technical benefits of BIM and Lean adoption, while this study adds to existing knowledge by revealing that coordination-oriented constructs play a more decisive role, especially in developing-country settings.

The study shows that the readiness and management support shape the effectiveness of BIM-Lean integration in the AEC industry in Palestine. This shows that BIM-Lean integration is not just about using new technology, but also about changing organizational and work practices. In practice, architectural firms need to focus on Design Coordination, since using BIM alone without proper coordination limits its ability to enhance efficiency. For this reason, firms should adopt early interdisciplinary coordination and standardized workflows supported by shared BIM environments.

The findings of this study are relevant to the Palestinian AEC industry, where project delivery is fragmented, and management support is limited for digital transformation. In such contexts, BIM-Lean integration has the potential to address these obstacles and

improve efficiency, but its success depends heavily on the organizational and management readiness.

By identifying the main challenges and opportunities of BIM-Lean integration in Palestine, this study provides practical and contextual strategies that can inform educators and practitioners to support more effective and sustainable adoption strategies.

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Appendices

Appendix A

Arab American University

Ramallah site



الجامعة العربية الأمريكية
ARAB AMERICAN UNIVERSITY

Arab American University

Masters in Engineering Management

Thesis Title

Integrating Building Information Modeling and Lean Principles in Palestinian Architectural Design: Strategies for Enhancing Efficiency and Effectiveness

SPRING 2025

Rasha M. Jaafreh

Thank you for participating in this survey on the Integration of BIM-Lean.

This study explores how BIM can help lean practices in optimizing design workflows, and eliminating inefficiencies in the AEC industry focusing on the architectural design process in Palestine.

This research contributes to both academia and the AEC industry in Palestine by identifying key challenges and proposing practical strategies for the integration of BIM and lean methodologies. The study's findings will help architects, engineers, and policy makers enhance efficiency and sustainability in architectural design. Moreover, it will help promoting a modernizing and improving architectural design processes by addressing the challenges faces when implementing BIM-Lean, leading to better project outcomes, and making Palestine's architectural industry more sophisticated.

All responses will remain strictly confidential and will be used solely for academic research. The survey could take 10-15 minutes to complete. By proceeding, you confirm your consent to participate. Your participation is important to us and highly valued, and we sincerely appreciate your contribution to this study.

Researcher: Rasha Jaafreh

Section 1. General information

Please check (✓) the box that applies to you:

1. **Age:** 20-30 31-40 41-50 +50
2. **City:** Ramallah Hebron Nablus Bethlehem Jenin Tulkarm
 Other, please specify.....
3. **Firm type:** Architecture Civil Mechanical Electrical Other/Multiple
4. **Firm classification:** Consultant First Second Third Contracting
5. **Position:** Architect Engineer Manager Other, please specify.....
6. **Years of experience:** 0-5 6-10 11-15 +20
7. **Familiarity with Building Information Modeling (BIM/Revit):**
 Very Low Low Medium High Very High
8. **Familiarity with Lean (Just In Time, Last Planner System, Value Stream Map...)**
 Very Low Low Medium High Very High
9. **Do you or your organization currently use BIM/Revit on projects?**
 Yes, regularly Yes, occasionally Not currently Future plans Don't know
10. **Do you or your organization currently use Lean practices (e.g. Just In Time, Last Planner System, Value Stream Mapping...) on projects?**
 Yes, regularly Yes, occasionally Not currently Future plans Don't know

Section 2. BIM/Revit

Please check (✓) the option that applies to the current status of your organization in front of each of the following questions:

| Question/statement | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|-------------------|----------|---------|-------|----------------|
| We use BIM/Revit at multiple project stages (Design, Coordination, Construction) | | | | | |
| Our firm has formal BIM/Revit procedures and standards. | | | | | |
| BIM/Revit is mainly used as a 3D drafting tool rather than a full BIM process. | | | | | |
| BIM/Revit is used consistently across disciplines (Architecture, mechanical, electrical, structure) | | | | | |
| Using BIM/Revit has helped to reduce time and effort spent on making drawings and 3D models needed for different projects. | | | | | |
| BIM/Revit Models are shared using common formats such as IFC for interchange to allow seamless collaboration and data exchange with other software. | | | | | |

| | | | | | |
|--|--|--|--|--|--|
| BIM/Revit is integrated with other tools (4D/5D, scheduling, cost) | | | | | |
| BIM/Revit reduces design errors | | | | | |
| BIM/Revit reduces rework | | | | | |
| BIM/Revit reduces times spent on drawings such as plans, elevations, sections, details, and 3D models. | | | | | |
| BIM/Revit helps identifying clashes early (before licencing/construction stages) | | | | | |
| BIM/Revit shortens coordination time between disciplines. | | | | | |

Please check (✓) what applies to you (can be multiple):

1. BIM/Revit Barriers

Software license cost Hardware limits Skills gap No training

Resistance to change Lack of standards/CDE Limited management support

others (please

specify) _____

2. BIM Level self-check (what best describes your BIM maturity)

Level 0 (2D CAD only)

Level 1 (2D/3D; limited sharing)

Level 2 (Collaborative 3D; discipline models exchanged)

Level 3 (Integrated/ shared models with real time data)

Unsure

Section 3. Lean practices

Please check (✓) the option that applies to the current status of your organization in front of each of the following questions:

| Question/statement | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|--------------------------|-----------------|----------------|--------------|-----------------------|
| We use Just In Time delivery principles. | | | | | |
| We use Last Planner System for planning. | | | | | |
| We use Value Stream Mapping (VSM) or similar practices to remove waste. | | | | | |
| Standardized work procedures are documented and followed consistently. | | | | | |
| Continuous improvement (Kaizen) is part of the organization's routine. (regular meetings to improve the firm's efficiency). | | | | | |

| | | | | | |
|---|--|--|--|--|--|
| Management actively supports Lean practices. | | | | | |
| Lean practices reduce rework and variability. | | | | | |
| Using Lean helped to improve scheduling and tasks' flow. | | | | | |
| Employees are trained and empowered to identify and eliminate waste. | | | | | |
| Pull planning principles are used (work is released based on readiness and demand). | | | | | |
| Lean problem-solving tools (e.g. A3, 5 Why) are used to identify and eliminate root causes. | | | | | |
| Visual management tools (Kanban, dashboards) are used to track work progress. | | | | | |
| Lean helped improving interdisciplinary communication. | | | | | |

Please check (✓) what applies to you (can be multiple):

1. Lean Barriers

Lack of training Limited awareness Lack of support from management

Time pressure Resistance to change Applying Lean practices takes a lot of

needed time others, please specify

Section 4. BIM/Lean integration

Please check (✓) the option that applies to the current status of your organization in front of each of the following questions:

| Question/statement | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|-------------------|----------|---------|-------|----------------|
| Our organization actively uses BIM/Revit models to support lean planning practices such as Last Planner System. | | | | | |
| Management supports the adoption of BIM and Lean practices. | | | | | |
| Staff receive adequate training on BIM/Lean tools and methods. | | | | | |
| Employees are open to adopting new technologies and work methods. | | | | | |
| Integrating BIM-Lean reduces project time, effort, and material waste. | | | | | |
| Combining BIM-Lean improves coordination and reduces rework (Lean: meetings, continuous improvement, BIM: shared models and information). | | | | | |

| | | | | | |
|--|--|--|--|--|--|
| BIM-Lean enhances decision making in the early stages of design and planning. | | | | | |
| BIM-Lean contributes to better schedule performance. | | | | | |
| BIM-Lean practices improve cost performance and reduce overruns. | | | | | |
| BIM-Lean adoption increases overall client satisfaction. | | | | | |
| BIM-Lean adoption improves safety (hazard identification through models). | | | | | |
| There is a limited availability of skilled professionals in BIM/Lean which hinders its adoption. | | | | | |
| BIM-Lean enables timely, accurate, and reliable information flow across disciplines. | | | | | |
| BIM-Lean promotes collaboration, transparency, and continuous improvement among teams. | | | | | |
| Our organization plans to use BIM/Lean in the near future. | | | | | |

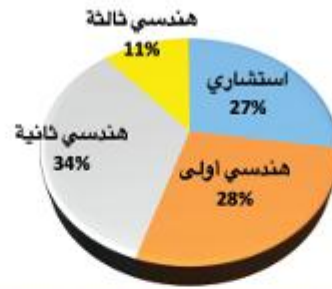
Appendix B

على صعيد العمل الهندسي الاستشاري

بلغ عدد المكاتب والشركات الهندسية المصنفة في النقابة حتى 2024/12/31 ما مجموعه 1071 مكتباً، منها 51 مكتباً جديداً تم تأسيسها منذ مطلع عام 2024. 1- توزيع المكاتب والشركات الهندسية المصنفة حسب مراتب التصنيف:

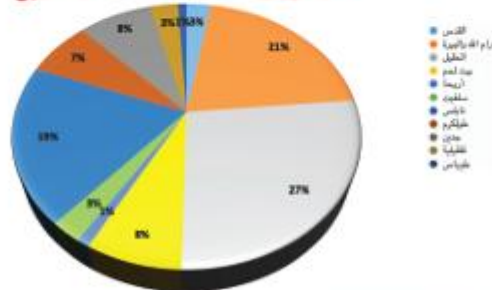
| المرتبة | العدد |
|-------------|-------|
| استشاري | 294 |
| هندسي أولى | 297 |
| هندسي ثانية | 363 |
| هندسي ثالثة | 121 |
| مهندس رأي | 01 |
| المجموع | 1076 |

نسب أعداد المكاتب الهندسية المصنفة لعام 2024



| الفرع | العدد |
|------------------|-------|
| الضلع | 29 |
| القدس | 224 |
| رام الله والبيرة | 289 |
| الخليل | 82 |
| بيت لحم | 11 |
| أريحا | 27 |
| سلفيت | 207 |
| نابلس | 76 |
| طولكرم | 87 |
| جنين | 34 |
| قلقيلية | 10 |
| طوباس | |

نسب توزيع المكاتب المصنفة حسب الفروع



Appendix C

Arab American University

Ramallah site



الجامعة العربية الأمريكية
ARAB AMERICAN UNIVERSITY

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Masters in Engineering Management

Thesis Title

Integrating Building Information Modeling and Lean Principles in Palestinian Architectural Design: Strategies for Enhancing Efficiency and Effectiveness

Fall 2025

Rasha M. Jaafreh

**Thank you for agreeing to participate in this interview on the Integration of BIM-
Lean.**

This study explores how BIM can help lean practices in optimizing design workflows, and eliminating inefficiencies in the AEC industry, focusing on the architectural design process in Palestine.

This research contributes to both academia and the AEC industry in Palestine by identifying key challenges and proposing practical strategies for the integration of BIM and lean methodologies. The study's findings will help architects, engineers, and policy makers enhance efficiency and sustainability in architectural design. Moreover, it will help to promote modernizing and improving architectural design processes by addressing the challenges faces when implementing BIM-Lean, leading to better project outcomes, and making Palestine's architectural industry more sophisticated.

Your participation in this interview is voluntary. All information shared during this interview will remain strictly confidential and will be used solely for academic research. Your identity and organization will not be disclosed in any publication or report resulting from this study.

The interview is expected to take 45-50 minutes. With your permission the interview will be audio recorded in order to ensure accuracy in data analysis. You may decline to answer any question or withdraw from the interview at any time.

By proceeding, you confirm your consent to participate. Your participation is important to us and highly valued, and we sincerely appreciate your contribution to this study.

Researcher: Rasha Jaafreh

Target participants

- **Primary focus:** Architects
- **Secondary:** Engineers, project managers, firm owners.

Interview questions

Section 1. Background and Role

1. Can you describe your role, years of experience, and the type of projects your firm typically works on?

Section 2. BIM and Lean adoption

2. How is BIM used in your organization during the architectural design process?
3. Which Lean practices, if any, are used during the design stage of your project, including coordination?

Section 3. BIM-Lean Integration

4. From your experience, how do BIM tools support Lean practices during the architectural design process?

Section 4. Design Coordination

5. How did the integration of BIM and Lean influence coordination between architects and other disciplines?

Section 5. Information Flow Quality

6. From your experience, how does BIM-Lean impact the quality, accuracy, and flow of information that is exchanged among project stakeholders?

Section 6. Collaborative Workflow

7. How did BIM-Lean impact teamwork? How did it impact communication and collaboration across multiple disciplines in your organization?

Section 7. Project Outcomes

8. From your experience, how has BIM-Lean impact project efficiency (waste reduction; e.g. rework)?

Section 8. Future Outlook

9. How do you see the future of BIM-Lean integration Palestine?

Section 9. Closing Question

10. Is there anything you would like to add concerning BIM, Lean, or collaboration in architectural design that has not been discussed?

Appendix D

HTMT Ratio with Bootstrapped Bias Corrected Confidence Intervals

| Construct Pair | HTMT | 2.50% | 97.5% |
|-----------------------|-------------|--------------|--------------|
| BL-CE | 1.184 | 1.086 | 1.326 |
| BL-CW | 1.032 | 0.953 | 1.113 |
| BL-DC | 0.973 | 0.908 | 1.044 |
| BL-EE | 1.066 | 0.972 | 1.179 |
| BL-IFQ | 1.184 | 1.076 | 1.337 |
| CE-CW | 0.813 | 0.704 | 0.897 |
| CE-DC | 1.022 | 0.960 | 1.084 |
| CE-EE | 1.077 | 1.014 | 1.155 |
| CE-IFQ | 1.140 | 1.043 | 1.272 |
| CW-DC | 0.512 | 0.367 | 0.643 |
| CW-EE | 0.611 | 0.485 | 0.716 |
| CW-IFQ | 0.845 | 0.705 | 0.976 |
| DC-EE | 1.026 | 0.976 | 1.075 |
| DC-IFQ | 0.996 | 0.908 | 1.087 |
| EE-IFQ | 1.052 | 0.937 | 1.174 |

(Source: SmartPLS, bootstrapping results)

عنوان الرسالة: دمج نمذجة معلومات البناء ومبادئ الممارسات الخالية من الهدر في

التصميم المعماري الفلسطيني: استراتيجيات لتحسين الكفاءة والفعالية

اسم الطالب الرباعي: رشا محمود عبد جعافرة

أسماء لجنة الاشراف:

د. أشرف الميمي

أ.د. إبراهيم محاميد

د. سامي صدر

ملخص

تتأثر عملية التصميم المعماري في كثير من الأحيان بتجزؤ سير العمل وبأنواع مختلفة من

الهدر, مما يؤدي الى تقليل كفاءة المشاريع, تم طرح دمج نمذجة المعلومات (BIM) مع مبادئ

الممارسات الخالية من الهدر (Lean) كنهج فعال لمعالجة هذه التحديات من خلال تحسين تنسيق

التصميم وجودة تدفق المعلومات وسير العمل التعاوني ضمن عملية التصميم. مع ذلك, لا تزال الأبحاث

التي تتنازل تطبيق تكامل BIM-Lean في سياقات مثل فلسطين محدودة. تهدف هذه الدراسة الى

فحص أثر تكامل BIM-Lean على تحسين الكفاءة في عملية التصميم المعماري في فلسطين.

تشير النتائج التي تم استخلاصها من منهج البحث المختلط المعتمد في الدراسة أن تكامل

BIM-Lean له أثر إيجابي على تعزيز الكفاءة وتقليل الهدر المرتبط بعملية التصميم المعماري, تبين

في الدراسة ان تنسيق التصميم هو العامل الأكثر تأثيرا من بين المتغيرات التي تم اقتراحها, واتضح ان

جودة تدفق المعلومات وسير العمل التعاوني يساهم في تعزيز الكفاءة وفعالية التعاون. على الرغم من

فوائد تكامل BIM-Lean العديدة تطبيقه الفعال في فلسطين لا يزال يواجه تحديات عديدة, أبرزها

العوائق التنظيمية ونقص المهارات والخبرات المتخصصة.

تلخص الدراسة ان تحقيق تطبيق ناجح وفعال لتكامل BIM-Lean يتطلب الجمع بين تبني

التقنيات التكنولوجية المناسبة وتوافر الالتزام والدعم على المستوى التنظيمي.

الكلمات المفتاحية: تكامل BIM-Lean, نمذجة معلومات البناء (BIM), مبادئ اللين, عملية التصميم

المعماري, تعزيز الكفاءة.